**Genetic correlation and hybrid vigor for physiological traits of** *Zea mays*

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**Abstract:** Present study was conducted in the glasshouse of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan during 2012. The experimental material was comprises of 10 inbred lines, 2 varieties and 36 F1 hybrids of maize. It was concluded that higher heritability and genetic advance was found for photosynthetic rate, chlorophyll contents, water use efficiency and sub-stomata CO2 concentration. Significant genotypic and phenotypic correlation was found for photosynthetic rate with water use efficiency, transpiration rate and stomata conductance while negatively and significantly correlated with leaf temperature and sub-stomata CO2 concentration. It was concluded that B-336 × B-316, EV-1097Q × EV-340, EV-1097Q × E-322, B-336 × Pop/209, B-336 × F-96, B-327 × F-96, B-327 × EV-340, B-327 × Pop/209, B-327 × E-322 showed higher heterosis and heterobeltiosis for all traits. Higher values of heritability, genetic advance, heterosis and heterobeltiosis indicated that selection of higher grain yielding maize genotypes of batter photosynthetic rate may be made on the basis of physiological traits of maize.

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**1. Introduction**

Maize (*Zea mays* L.) is an important cereal food crop in world and Pakistan where rapidly increasing population has run short of food supplies. Maize is the third very important cereal in Pakistan after wheat and rice. Maize contributes 5.67 % of GDP of agriculture products. It was grown on 1083 thousands hectares with annual production of 4271 thousands tons (Anonymous, 2011-12). Maize is used as food for human while feed for livestock and also used as industrial raw material to produce a large number of maize by-products. Its grain constitutes about 9.7396 % grain protein, 4.85% grain oil, 9.4392% grain crude fibre, 71.966% grain starch, 11.77% embryo while fodder contains 22.988% acid detergent fibre, 51.696% neutral detergent fibre, 28.797% fodder cellulose, 40.178% fodder dry matter, 26.845% fodder crude fibre, 10.353% fodder crude protein and 9.095% fodder moisture [Ali *et al*., 2014ab]. Production of Pakistan is very low than other maize producing countries due to non-availability of potential germplasm and resources. Grain yield of maize is associated with different morphological, physiological and agronomic traits. By improving these traits production of maize may be improved. Genetic correlation provides a chance to a plant breeder to select genotypes on the basis of strong correlation among grain yielding contributing traits as reported by Mehdi and Ahsan (2000); Grzesiak *et al.* (2007); Ali *et al.* (2011a, b) and Ali *et al.* (2012). The present study was conducted to evaluate maize accessions for physiological seedling traits.

**Materials and methods**

The present study was carried out in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad to evaluate maize genotypes for seedling traits for the period of the crop season in February 2012. The experimental material comprised of 10 inbred lines, 2 varieties and 36 crosses as given below (Table 1):

The seeds of all parents and F1 hybrids were sown in iron trays filled with sand following a completely randomized design (CRD) with three replications at the depth of 2.5 cm and twenty seedlings of each parents and F1 hybrids were established in each replication. The data of 5 plants was recorded for physiological traits including chlorophyll contents measured with the help of Chlorophyll Meter and leaf temperature, stomata conductance, transpiration rate, photosynthetic rate, sub-stomata CO2 concentration, water use efficiency help of IRGA (Infrared Gas Analyzer). The data was statistically analyzed by using analysis of variance technique (Steel *et* *al*. 1997). The genotypic and phenotypic correlations were calculated by Kwon and Torrie (1964) technique. The genetic advance was calculated by using Falconer (1989) formula. Heritability was recorded by using Burton, (1951) technique.

**Table 1: Experimental germplasm**

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

**Results and discussions**

It was found from table 2 that significant differences were recorded for all traits. The heritability was found from 60.708-99.796% while genetic advance was found from 8.287-185.379%. Highest heritability and genetic advance were recorded for water use efficiency while lower for stomata conductance. Higher heritability and genetic advance indicated that selection of higher grain and fodder yielding maize genotypes may be helpful to improve crop yield. Similar results were obtained by Mehdi and Ahsan (2000); Grzesiak *et al.* (2007); Ali *et al.* 2014abc; Ali *et al.* (2011a, b) and Ali *et al.* (2012). It was found from figure 1 that highest photosynthetic rate was reported for B-336 × Pop/209 while lowest for B-327. Highest leaf temperature was recorded for EV-1097Q × Pop/209 while lowest for B-336 × F-96 (Figure 2). The highest chlorophyll contents were recorded for B-11 × EV-347 while lowest for EV-340 (Figure 3). Highest stomata conductance was recorded for B-11 × EV-347 while lowest for B-11 × Pop/209 (Figure 4). Figure 5 indicated that transpiration rate was found higher for B-11 × EV-347, B-336 × Pop/209 while lowest for B-327 × Pop/209 and Raka-poshi. It was suggested from figure 6 that highest sub-stomata CO2 concentration was found for Sh-139 while lowest for B-336 × Pop/209. Highest water use efficiency was found for B-336 × EV-347 while lowest for EV-347 and Sh-139 × EV-347 (Figure 7). Similar results were reported by Ali *et al.* (2012). It was persuaded from table 3 that significant genotypic and phenotypic correlation of chlorophyll contents was found photosynthetic rate while negatively and significantly correlated with stomata CO2 concentration and water use efficiency. Photosynthetic rate was positively and significantly correlated with chlorophyll contents, transpiration rate, stomata conductance and water use efficiency while negatively correlated with stomata CO2 concentration and leaf temperature at genotypic and phenotypic levels. Leaf temperature was positively and significantly correlated with transpiration rate, stomata CO2 concentration and water use efficiency at genotypic and phenotypic levels. Significant and positive genotypic and phenotypic correlations indicated that selection of higher yielding maize genotypes for photosynthetic rate, chlorophyll contents and water use efficiency may be help to improve maize production. Similar results were obtained by Mehdi and Ahsan (2000a); Grzesiak *et al.* (2007); Ali and Ahsan (2011); Ahsan *et al.* (2011); Ali *et al.* (2011a, b); Ali *et al.* (2012) and Tariq *et al.* (2014).

It was persuaded from table 4 that higher heterosis and heterobeltiosis for photosynthetic rate was recorded for B-11 × EV-340 (356.288, 161.068), B-327 × EV-340 (226.419, 135.593), B-327 × E-322 (647.867, 311.712), Raka-poshi × B-316 (651.886, 624.561) and Raka-poshi × EV-340 (635.724, 594.236) respectively, while lower for B-336 × EV-347 (-93.237, -89.306) and B-336 × EV-347 (-87.666, -89.306) respectively.

**Table 2: Genetic components for various physiological traits of maize**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Traits** | **M.S** | **G.M** | **GV** | **GCV %** | **PV** | **PCV %** | **EV** | **ECV %** | **h2bs%** | **GA%** |
| **Photosynthetic rate** | 105.520\* | 68.103 | 35.050 | 71.740 | 35.420 | 72.118 | 0.370 | 7.371 | 98.955 | 95.039 |
| **Leaf Temperature** | 4.217\*\* | 33.892 | 1.399 | 20.315 | 1.419 | 20.461 | 0.020 | 2.441 | 98.576 | 26.913 |
| **Chlorophyll contents** | 0.624\*\* | 0.366 | 0.206 | 75.042 | 0.211 | 76.002 | 0.005 | 12.044 | 97.489 | 99.413 |
| **Stomata conductance** | 0.00048\*\* | 0.034 | 0.00013 | 6.255 | 0.00021 | 8.028 | 0.00008 | 5.032 | 60.708 | 8.287 |
| **Transpiration rate** | 0.514\*\* | 0.671 | 0.171 | 50.497 | 0.172 | 50.587 | 0.001 | 3.015 | 99.645 | 66.897 |
| **Sub-Stomata CO2 concentration** | 154893\* | 274.930 | 51578 | 1369.685 | 51737 | 1371.795 | 159.000 | 76.048 | 99.693 | 144.75 |
| **Water use efficiency** | 865.800\* | 16.061 | 288.403 | 423.749 | 288.993 | 424.182 | 0.590 | 19.166 | 99.796 | 185.379 |

**Table 3: Genotypic and phenotypic correlation for various physiological traits of maize**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Traits** | **r** | **Photosynthetic rate** | **Chlorophyll contents** | **Sub-Stomata CO2 concentration** | **Transpiration rate** | **Leaf Temperature** | **Water use efficiency** |
| **Chlorophyll contents** | g | 0.4569\* |  |  |  |  |  |
|  | p | 0.3867\*\* |  |  |  |  |  |
| **Sub-Stomata CO2 concentration** | g | -0.5236\* | -0.2165\*\* |  |  |  |  |
|  | p | -0.2314\*\* | -0.0342 |  |  |  |  |
| **Transpiration rate** | g | 0.3125\*\* | -0.1228 | 0.0551 |  |  |  |
|  | p | 0.3451\*\* | -0.1086 | 0.0453 |  |  |  |
| **Leaf Temperature** | g | -0.2459\*\* | -0.1205 | 0.3697\*\* | 0.4608\* |  |  |
|  | p | -0.2133\*\* | -0.0754 | 0.4563\* | 0.5764\* |  |  |
| **Water use efficiency** | g | 0.4948\* | -0.2365\*\* | 0.1815 | 0.4074\* | 0.2537\*\* |  |
|  | p | 0.5643\* | -0.3213\*\* | 0.1886 | 0.4352\* | 0.2876\*\* |  |
| **Stomata conductance** | g | 0.2077\*\* | 0.0036 | -0.2196\*\* | 0.178 | 0.0891 | -0.0465 |
|  | p | 0.2412\*\* | 0.0564 | -0.3421\*\* | 0.1902 | 0.0987 | -0.0036 |

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

Higher heterosis and heterbeltiosis suggested that the hybrids may be developed fro the improvement of green fodder yield on the basis of higher photosynthetic rate (Khan *et al.* (2001); Akhtar (2002); Alvi *et al.* (2003) and Vafias *et al.* 2005; Ali *et al.* 2013abc). It was suggested from table 4 that higher heterosis and heterobeltiosis for leaf temperature was recorded for B-336 × B-316 (6.315, 5.424), EV-1097Q × EV-340 (6.746, 6.268) and EV-1097Q × E-322 (6.905, 6.746) respectively, while lower for B-336 × E-322 (-7.121, -7.396) and B-336 × F-96 (-9.244, -9.960) respectively. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was shown from table 5 that higher heterosis and heterobeltiosis for chlorophyll contents was recorded for B-336 × Pop/209 (6525.53, 6387.50), B-336 × E-322 (3020.56, 1911.45), B-336 × F-96 (7197.62, 6285.42), EV-1097Q × EV-340 (2067.13, 1328.11) and B-327 × F-96 (2116.49, 1172.43) respectively, while lower for EV-1097Q × B-316 (-96.06, -97.90), EV-1097Q × EV-347 (94.58, 97.10) and B-336 × B-316 (-93.79, -96.85) respectively. Higher heterosis and heterobeltiosis for chlorophyll content suggested that the hybrid vigor will be higher that caused to improve photosynthetic rate to enhance of accumulation of organic compounds. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was persuaded from table 5 that higher heterosis and heterobeltiosis for stomata conductance was recorded for B-327 × Pop/209 (183.333, 183.333), B-327 × E-322 (142.857, 112.50), B-327 × EV-340 (209.091, 183.333), B-327 × B-316 (100.00, 66.667) and EV-1097Q × Pop/209 (110.00, 75.00) respectively, while lower for B-11 × Pop/209 (-60.00, -71.429), B-11 × F-96 (-51.724, -53.333) and B-336 × F-96 (-53.333, -53.333) respectively. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was found from table 6 that higher heterosis and heterobeltiosis for transpiration rate was recorded for Raka-poshi × Pop/209 (264.602, 145.238), Raka-poshi × E-322 (125.225, 29.534), Raka-poshi × EV-347 (553.521, 452.381), Raka-poshi × B-316 (523.881, 450.00) and Raka-poshi × EV-340 (369.880, 261.11) respectively, while lower for B-336 × E-322 (-54.351, -66.587), B-336 × F-96 (-69.464, -73.317) and Sh-139 × EV-347 (-65.482, -78.065) respectively. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was persuaded from table 6 that higher heterosis and heterobeltiosis for sub-stomata CO2 concentration was recorded for B-336 × B-316 (680.00, 380.698), EV-1097Q × E-322 (705.536, 465.049), Raka-poshi × EV-347 (404.444, 247.893) and EV-1097Q × EV-347 (657.295, 437.374) respectively, while lower for B-336 × EV-340 (-89.364, -93.987), B-327 × E-322 (-86.732, -92.852) and Sh-139 × EV-340 (-95.915, -97.401) respectively. Higher sub-stomata CO2 concentration suggested that the amount of organic compounds may be increased due to higher photosynthetic rate. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was suggested from table 7 that higher heterosis and heterobeltiosis for water use efficiency was recorded for B-336 × EV-347 (1572.04, 850.998), EV-1097Q × B-316 (727.10, 423.553), EV-1097Q × B-316 (304.56, 288.418) and Raka-poshi × EV-347 (290.80, 133.109) respectively, while lower for B-327 × E-322 (-95.93, -97.135), B-327 × EV-340 (-68.06, -76.056), Sh-139 × F-96 (-82.94, -90.579) and Sh-139 × EV-347 (-96.27, -98.078) respectively. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). Higher heterosis and heterobeltiosis indicated that selection may be helpful for the development of hybrids for higher grain and fodder yield of maize.



**Table 4: Heterosis and heterobeltiosis for Photosynthetic rate and leaf temperature**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Photosynthetic** | **Rate** |  |  | **Leaf** | **Temperature** |  |  |
| **Parents/Crosses** | **Heterosis** | **Heterobeltosis** | **t\_Hetr** | **t\_Hetrb** | **Heterosis** | **Heterobeltosis** | **t\_Hetr** | **t\_Hetrb** |
| B-11xPop/209 | -19.674 | -25.000 | -4.671 | -5.505 | 2.374 | 0.976 | 9.181 | 3.313 |
| B-11xB-316 | 24.478 | -28.373 | 3.107 | -5.420 | 2.967 | 1.561 | 11.476 | 5.301 |
| B-11xEV-340 | 356.288 | 161.068 | 44.962 | 30.766 | 1.633 | 0.195 | 6.312 | 0.663 |
| B-11xE-322 | -15.248 | -30.779 | -2.747 | -5.879 | 2.705 | 1.854 | 10.520 | 6.295 |
| B-11xF-96 | -49.935 | -65.866 | -20.654 | -34.605 | 4.795 | 3.415 | 18.554 | 11.595 |
| B-11xEV-347 | -36.320 | -42.065 | -8.893 | -9.804 | 4.691 | 3.415 | 18.171 | 11.595 |
| B-336xPop/209 | 133.715 | 97.915 | 41.509 | 31.085 | 5.818 | 4.931 | 22.379 | 16.565 |
| B-336xB-316 | -27.592 | -60.510 | -5.516 | -19.210 | 6.315 | 5.424 | 24.292 | 18.221 |
| B-336xEV-340 | -36.628 | -65.563 | -7.297 | -20.814 | -0.995 | -1.874 | -3.826 | -6.295 |
| B-336xE-322 | -39.691 | -58.352 | -10.048 | -18.525 | -7.122 | -7.396 | -27.543 | -24.847 |
| B-336x F-96 | -93.237 | -94.575 | -45.371 | -49.688 | -9.245 | -9.961 | -35.577 | -33.461 |
| B-336x EV-347 | -87.666 | -89.306 | -27.865 | -28.352 | 4.866 | 4.142 | 18.745 | 13.914 |
| EV-1097Qx Pop/209 | -74.252 | -77.016 | -16.855 | -16.960 | 2.797 | 2.388 | 10.711 | 7.951 |
| EV-1097Qx B-316 | -48.205 | -69.788 | -5.615 | -12.070 | 5.295 | 4.876 | 20.275 | 16.234 |
| EV-1097Qx EV-340 | -19.534 | -53.354 | -2.261 | -9.227 | 6.747 | 6.269 | 25.822 | 20.872 |
| EV-1097QxE-322 | -12.689 | -25.799 | -2.154 | -4.462 | 6.905 | 6.746 | 26.587 | 22.528 |
| EV-1097QxF-96 | -66.012 | -77.412 | -26.615 | -40.671 | 2.446 | 2.090 | 9.372 | 6.957 |
| EV-1097QxEV-347 | -25.240 | -34.881 | -5.916 | -8.130 | -0.648 | -0.896 | -2.487 | -2.982 |
| B-327xPop/209 | -74.807 | -86.704 | -10.039 | -19.093 | -1.877 | -3.311 | -7.268 | -11.264 |
| B-327xB-316 | 80.266 | 28.378 | 1.902 | 0.818 | -1.581 | -3.019 | -6.121 | -10.270 |
| B-327xEV-340 | 226.419 | 135.593 | 5.202 | 3.738 | 1.434 | -0.097 | 5.547 | -0.331 |
| B-327xE-322 | 647.867 | 311.712 | 49.835 | 37.720 | -1.229 | -2.142 | -4.782 | -7.289 |
| B-327xF-96 | -19.032 | -58.574 | -5.907 | -30.774 | -0.543 | -1.947 | -2.104 | -6.626 |
| B-327xEV-347 | 82.730 | -3.842 | 11.716 | -0.896 | -0.641 | -1.947 | -2.487 | -6.626 |
| Raka-poshixPop/209 | 62.628 | -7.214 | 9.086 | -1.589 | 0.739 | -1.064 | 2.869 | -3.644 |
| Raka-poshixB-316 | 651.886 | 624.561 | 22.537 | 19.405 | 1.428 | -0.387 | 5.547 | -1.325 |
| Raka-poshixEV-340 | 635.724 | 594.236 | 21.521 | 18.463 | 1.084 | -0.774 | 4.208 | -2.650 |
| Raka-poshixE-322 | 162.161 | 64.736 | 14.238 | 7.834 | 0.784 | -0.484 | 3.060 | -1.657 |
| Raka-poshixF-96 | -69.941 | -84.082 | -22.470 | -44.175 | -0.689 | -2.418 | -2.678 | -8.282 |
| Raka-poshixEV-347 | -19.281 | -54.260 | -2.940 | -12.646 | -1.573 | -3.191 | -6.121 | -10.933 |
| Sh-139xPop/209 | 12.075 | -36.987 | 1.726 | -8.145 | 4.536 | 2.813 | 17.597 | 9.608 |
| Sh-139xB-316 | 97.784 | 92.973 | 3.174 | 2.679 | 5.030 | 3.298 | 19.510 | 11.264 |
| Sh-139xEV-340 | 181.020 | 180.226 | 5.746 | 4.968 | -5.871 | -7.468 | -22.762 | -25.510 |
| Sh-139xE-322 | -1.049 | -39.318 | -0.090 | -4.758 | -4.169 | -5.238 | -16.258 | -17.890 |
| Sh-139xF-96 | -21.257 | -58.574 | -6.784 | -30.774 | -6.358 | -7.856 | -24.674 | -26.835 |
| Sh-139xEV-347 | 140.120 | 34.180 | 21.072 | 7.966 | -5.170 | -6.596 | -20.084 | -22.528 |

**Table 5: Heterosis and heterobeltiosis for Chlorophyll contents and stomata conductance**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Chlorophyll** | **contents** |  |  | **Stomata** | **Conductance** |  |  |
| **Parents/Crosses** | **Heterosis** | **Heterobeltosis** | **t\_Hetr** | **t\_Hetrb** | **Heterosis** | **Heterobeltosis** | **t\_Hetr** | **t\_Hetrb** |
| B-11xPop/209 | 675.560 | 658.700 | 2.270 | 1.960 | -60.000 | -71.429 | -3.527 | -5.090 |
| B-11xB-316 | -87.560 | -93.690 | -10.720 | -19.602 | -30.435 | -42.857 | -2.057 | -3.054 |
| B-11xEV-340 | 123.010 | 82.610 | 0.519 | 0.369 | 36.842 | -7.143 | 2.057 | -0.509 |
| B-11xE-322 | 68.570 | 6.630 | 0.538 | 0.071 | 0.000 | -21.429 | 0.000 | -1.527 |
| B-11xF-96 | 332.500 | 293.180 | 0.993 | 0.834 | -51.724 | -53.333 | -4.408 | -4.072 |
| B-11xEV-347 | 116.010 | 9.550 | 13.475 | 1.895 | 30.769 | 21.429 | 2.351 | 1.527 |
| B-336xPop/209 | 6525.530 | 6387.500 | 22.903 | 19.828 | 4.762 | -26.667 | 0.294 | -2.036 |
| B-336xB-316 | -93.790 | -96.850 | -11.496 | -20.261 | -33.333 | -46.667 | -2.351 | -3.563 |
| B-336xEV-340 | 491.450 | 401.450 | 2.147 | 1.791 | 30.000 | -13.333 | 1.763 | -1.018 |
| B-336xE-322 | 3020.560 | 1911.450 | 24.135 | 20.520 | 13.043 | -13.333 | 0.882 | -1.018 |
| B-336xF-96 | 7197.620 | 6285.420 | 22.574 | 19.511 | -53.333 | -53.333 | -4.702 | -4.072 |
| B-336xEV-347 | -93.000 | -96.450 | -10.817 | -19.130 | -25.926 | -33.333 | -2.057 | -2.545 |
| EV-1097QxPop/209 | -27.760 | -56.220 | -0.273 | -0.789 | 100.000 | 75.000 | 4.114 | 3.054 |
| EV-1097QxB-316 | -96.060 | -97.900 | -12.381 | -20.481 | 64.706 | 55.556 | 3.233 | 2.545 |
| EV-1097QxEV-340 | 2067.130 | 1328.110 | 22.074 | 18.638 | 23.077 | 0.000 | 0.882 | 0.000 |
| EV-1097QxE-322 | -60.310 | -64.980 | -0.863 | -0.912 | 12.500 | 12.500 | 0.588 | 0.509 |
| EV-1097QxF-96 | -2.770 | -43.320 | -0.026 | -0.608 | -39.130 | -53.333 | -2.645 | -4.072 |
| EV-1097QxEV-347 | -94.580 | -97.100 | -11.597 | -19.259 | 10.000 | -8.333 | 0.588 | -0.509 |
| B-327xPop/209 | 67.470 | -0.410 | 0.728 | -0.007 | 183.333 | 183.333 | 6.465 | 5.599 |
| B-327xB-316 | -89.480 | -94.340 | -11.619 | -19.737 | 100.000 | 66.667 | 4.408 | 3.054 |
| B-327xEV-340 | 42.950 | -8.230 | 0.500 | -0.129 | 209.091 | 183.333 | 6.759 | 5.599 |
| B-327xE-322 | 1455.990 | 1209.470 | 22.234 | 19.007 | 142.857 | 112.500 | 5.877 | 4.581 |
| B-327xF-96 | 2116.490 | 1172.430 | 22.048 | 18.425 | -42.857 | -60.000 | -2.645 | -4.581 |
| B-327xEV-347 | 22.360 | -33.970 | 2.764 | -6.738 | 0.000 | -25.000 | 0.000 | -1.527 |
| Raka-poshixPop/209 | -38.910 | -67.470 | -1.094 | -3.085 | 33.333 | 0.000 | 1.763 | 0.000 |
| Raka-poshixB-316 | 58.800 | -3.250 | 8.655 | -0.679 | 4.762 | -8.333 | 0.294 | -0.509 |
| Raka-poshixEV-340 | 679.900 | 328.010 | 19.699 | 14.997 | 64.706 | 16.667 | 3.233 | 1.018 |
| Raka-poshixE-322 | 626.920 | 348.800 | 20.435 | 15.948 | 0.000 | -16.667 | 0.000 | -1.018 |
| Raka-poshixF-96 | -86.000 | -92.640 | -2.386 | -4.236 | 3.704 | -6.667 | 0.294 | -0.509 |
| Raka-poshixEV-347 | -96.290 | -97.720 | -13.568 | -19.382 | -25.000 | -25.000 | -1.763 | -1.527 |
| Sh-139xPop/209 | 1455.880 | 774.390 | 22.668 | 18.580 | -27.273 | -33.333 | -0.882 | -1.018 |
| Sh-139xB-316 | -90.460 | -94.680 | -12.180 | -19.809 | 42.857 | 11.111 | 1.763 | 0.509 |
| Sh-139xEV-340 | 120.910 | 31.000 | 1.986 | 0.744 | 0.000 | 0.000 | 0.000 | 0.000 |
| Sh-139xE-322 | 33.330 | -3.500 | 0.668 | -0.084 | 23.077 | 0.000 | 0.882 | 0.000 |
| Sh-139xF-96 | 138.820 | 31.000 | 2.110 | 0.744 | -50.000 | -66.667 | -2.939 | -5.090 |
| Sh-139xEV-347 | 78.820 | 0.230 | 10.118 | 0.045 | -29.412 | -50.000 | -1.469 | -3.054 |

**Table 6: Heterosis and heterobeltiosis for Transpiration rate and Sub-stomata CO**2 **concentration**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Transpiration** | **Rate** |  |  | **Sub-Stomata** | **CO**2 **Concentration** |  |  |
| **Parents/Crosses** | **Heterosis** | **Heterobeltosis** | **t\_Hetr** | **t\_Hetrb** | **Heterosis** | **Heterobeltosis** | **t\_Hetr** | **t\_Hetrb** |
| B-11xPop/209 | 2.372 | -38.626 | 1.318 | -31.017 | 286.678 | 209.030 | 73.324 | 57.935 |
| B-11xB-316 | 63.043 | -11.137 | 31.860 | -8.943 | 95.051 | 54.043 | 24.024 | 14.979 |
| B-11xEV-340 | 75.630 | -0.948 | 39.550 | -0.761 | 142.070 | 138.431 | 46.173 | 39.557 |
| B-11xE-322 | -24.878 | -45.261 | -16.809 | -36.345 | -12.658 | -44.205 | -2.588 | -12.252 |
| B-11xF-96 | -44.065 | -51.422 | -35.485 | -41.292 | 45.066 | 32.749 | 13.198 | 9.077 |
| B-11xEV-347 | 88.362 | 3.555 | 45.043 | 2.854 | 304.468 | 156.199 | 61.722 | 43.292 |
| B-336xPop/209 | 74.000 | 4.567 | 40.649 | 3.615 | -90.809 | -94.369 | -10.654 | -15.651 |
| B-336xB-316 | 2.203 | -44.231 | 1.099 | -35.013 | 680.000 | 380.698 | 77.724 | 61.147 |
| B-336xEV-340 | -5.532 | -46.635 | -2.856 | -36.915 | -89.364 | -93.987 | -16.670 | -26.857 |
| B-336x E-322 | -54.351 | -66.587 | -36.364 | -52.709 | 162.745 | 95.146 | 10.740 | 7.321 |
| B-336x F-96 | -69.464 | -73.317 | -55.480 | -58.037 | 24.581 | -27.597 | 3.796 | -6.350 |
| B-336x EV-347 | 84.716 | 1.683 | 42.626 | 1.332 | 206.040 | 130.303 | 13.242 | 9.637 |
| EV-1097Qx Pop/209 | 128.916 | 53.226 | 47.021 | 25.118 | 166.414 | 58.108 | 18.913 | 9.637 |
| EV-1097QxB-316 | 103.497 | 17.339 | 32.519 | 8.182 | 103.509 | 21.395 | 11.452 | 3.436 |
| EV-1097QxEV-340 | 35.099 | -17.742 | 11.645 | -8.373 | 39.387 | -22.745 | 7.203 | -6.499 |
| EV-1097QxE-322 | -12.018 | -21.774 | -5.823 | -10.275 | 705.536 | 465.049 | 43.973 | 35.784 |
| EV-1097QxF-96 | -48.837 | -54.019 | -29.992 | -31.968 | 194.134 | 66.883 | 29.265 | 15.390 |
| EV-1097QxEV-347 | -48.276 | -69.758 | -15.381 | -32.919 | 657.295 | 437.374 | 39.832 | 32.348 |
| B-327xPop/209 | -63.636 | -71.429 | -9.228 | -11.417 | -32.685 | -60.689 | -21.760 | -59.915 |
| B-327xB-316 | 0.000 | -10.417 | 0.000 | -0.951 | -28.083 | -58.191 | -18.611 | -57.449 |
| B-327xEV-340 | 19.608 | 12.963 | 2.197 | 1.332 | -52.993 | -69.694 | -38.948 | -68.805 |
| B-327xE-322 | -53.527 | -70.984 | -14.172 | -26.069 | -86.732 | -92.849 | -53.289 | -91.665 |
| B-327xF-96 | -4.735 | -45.016 | -1.868 | -26.640 | -69.438 | -81.158 | -48.804 | -80.123 |
| B-327xEV-347 | 248.889 | 227.083 | 24.609 | 20.741 | -70.785 | -84.298 | -43.369 | -83.223 |
| Raka-poshixPop/209 | 264.602 | 145.238 | 32.849 | 23.215 | 16.977 | 8.238 | 3.537 | 1.606 |
| Raka-poshixB-316 | 523.881 | 450.000 | 38.561 | 32.539 | 40.966 | 28.544 | 8.411 | 5.566 |
| Raka-poshixEV-340 | 369.880 | 261.111 | 33.728 | 26.830 | 9.557 | -7.843 | 2.653 | -2.241 |
| Raka-poshixE-322 | 125.225 | 29.534 | 30.542 | 10.846 | 42.857 | -0.383 | 6.729 | -0.075 |
| Raka-poshixF-96 | 32.941 | -27.331 | 12.305 | -16.174 | -30.756 | -36.039 | -7.548 | -8.292 |
| Raka-poshixEV-347 | 553.521 | 452.381 | 43.176 | 36.154 | 404.444 | 247.893 | 62.800 | 48.335 |
| Sh-139xPop/209 | 111.715 | 63.226 | 29.333 | 18.648 | -1.568 | -43.005 | -1.100 | -45.123 |
| Sh-139xB-316 | 176.684 | 72.258 | 37.463 | 21.312 | -20.531 | -54.183 | -14.341 | -56.852 |
| Sh-139xEV-340 | 138.278 | 60.645 | 31.750 | 17.887 | -95.915 | -97.401 | -73.928 | -102.198 |
| Sh-139xE-322 | -43.103 | -48.705 | -16.479 | -17.887 | -61.327 | -79.245 | -39.875 | -83.148 |
| Sh-139xF-96 | -50.215 | -62.701 | -25.708 | -37.106 | -76.818 | -85.867 | -56.740 | -90.096 |
| Sh-139xEV-347 | -65.482 | -78.065 | -14.172 | -23.025 | -80.047 | -89.320 | -51.909 | -93.719 |

**Table 7: Heterosis and heterobeltiosis for water use efficiency**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parents/Crosses** | **Hetr** | **Hetrb** | **t\_Hetr** | **t\_Hetrb** | **Parents/Crosses** | **Hetr** | **Hetrb** | **t\_Hetr** | **t\_Hetrb** |
| B-11xPop/209 | 21.070 | -29.010 | 4.500 | -9.150 | B-327xPop/209 | -61.920 | -79.109 | -21.975 | -44.320 |
| B-11xB-316 | 55.360 | 24.075 | 16.102 | 7.594 | B-327xB-316 | -55.650 | -70.370 | -24.055 | -39.424 |
| B-11xEV-340 | -59.780 | -62.056 | -20.543 | -19.574 | B-327xEV-340 | -68.060 | -76.056 | -33.007 | -42.609 |
| B-11xE-322 | -8.140 | -20.912 | -2.553 | -6.596 | B-327xE-322 | -95.930 | -97.135 | -43.639 | -54.418 |
| B-11xF-96 | -18.380 | -48.254 | -4.244 | -15.220 | B-327xF-96 | -65.200 | -79.976 | -24.271 | -44.805 |
| B-11xEV-347 | 170.910 | 46.504 | 33.662 | 14.668 | B-327xEV-347 | -65.860 | -82.146 | -22.281 | -46.021 |
| B-336xPop/209 | -16.930 | -46.370 | -2.360 | -8.674 | Raka-poshixPop/209 | 53.330 | 7.982 | 5.781 | 1.064 |
| B-336xB-316 | 40.750 | 40.255 | 8.834 | 7.584 | Raka-poshixB-316 | -17.590 | -29.643 | -3.268 | -5.585 |
| B-336xEV-340 | 24.210 | 3.634 | 6.525 | 1.017 | Raka-poshixEV-340 | -37.500 | -53.860 | -8.943 | -15.068 |
| B-336xE-322 | -27.630 | -34.085 | -6.616 | -7.761 | Raka-poshixE-322 | -0.800 | -21.361 | -0.166 | -4.864 |
| B-336xF-96 | 309.580 | 197.321 | 48.543 | 36.912 | Raka-poshixF-96 | 254.250 | 189.424 | 31.975 | 25.252 |
| B-336xEV-347 | 1572.040 | 850.998 | 193.137 | 159.194 | Raka-poshixEV-347 | 290.800 | 133.109 | 26.701 | 17.744 |
| EV-1097QxPop/209 | 727.100 | 423.553 | 108.810 | 86.719 | Sh-139xPop/209 | -39.610 | -67.769 | -19.717 | -54.737 |
| EV-1097QxB-316 | 304.560 | 288.418 | 69.130 | 59.051 | Sh-139xB-316 | 37.670 | -15.109 | 21.664 | -12.203 |
| EV-1097QxEV-340 | 49.040 | 29.062 | 13.719 | 8.130 | Sh-139xEV-340 | -15.360 | -43.019 | -9.641 | -34.746 |
| EV-1097QxE-322 | -0.180 | -5.211 | -0.044 | -1.187 | Sh-139xE-322 | -60.170 | -74.470 | -35.969 | -60.149 |
| EV-1097QxF-96 | 18.950 | -15.970 | 3.165 | -3.270 | Sh-139xF-96 | -82.940 | -90.579 | -42.725 | -73.160 |
| EV-1097QxEV-347 | -38.770 | -65.540 | -5.159 | -13.419 | Sh-139xEV-347 | -96.270 | -98.078 | -46.325 | -79.217 |

**Conclusions**

It was concluded that B-336 × B-316, EV-1097Q × EV-340, EV-1097Q × E-322, B-336 × Pop/209, B-336 × F-96, B-327 × F-96, B-327 × EV-340, B-327 × Pop/209, B-327 × E-322 showed higher heterosis and heterobeltiosis for all traits. Higher values of heritability, genetic advance, heterosis and heterobeltiosis indicated that selection of higher grain yielding maize genotypes of batter photosynthetic rate may be made on the basis of physiological traits of maize.

**Reference**:

1. Abbas, SQ, MUl Hassan, B Hussain, T Rasool and Q Ali. 2014. Optimization of zinc seed priming treatments for improving the germination and early seedling growth of*Oryza sativa*. Adv. life sci., 2(1) pp: Advance Online Publications.
2. Akhtar, N. 2002. Heterosis and genetic analysis of seedling traits in maize. AGRIS. Pp: 93.
3. Ali A, Muzaffar A, Awan MF, Ud Din S, Nasir IA. 2014. Genetically Modified Foods: Engineered tomato with extra advantages. Adv. Life Sci*.*, 1 (3): 139-152.
4. Ahsan M, Farooq A, Khaliq I, Ali Q, Aslam M, Kashif M: Inheritance of various yield contributing traits in maize (*Zea mays* L.) at low moisture condition. African J. Agri. Res. 2013, 8(4): 413-420.
5. Ali, Q., M. Ahsan, M. H. N. Tahir, M. Elahi, J. Farooq, M. Waseem, M. Sadique, 2011a. Genetic variability for grain yield and quality traits in chickpea (Cicer arietinum L.). *IJAVMS*,  [5(2)](http://www.scopemed.org/?jid=25&iid=2011-5-2.000): 201-208.
6. Ali, Q.,M. Elahi**,** M. Ahsan, M. H. N. Tahir and **S. M. A.Basra**, Genetic evaluation of maize (*Zea mays* L.) genotypes at seedling stage under moisture stress. 2011b. *IJAVMS*, 5(2):184-193.
7. Ali, Q., M. Ahsan, M.H.N. Tahir & S.M.A. Basra. 2012. Genetic evaluation of maize (Zea mays L.) accessions for growth related seedling traits. IJAVMS, 6(3): 164-172.
8. Ali Q, Ahsan M, Ali F, Aslam M, Khan NH, Munzoor M, Mustafa HSB, Muhammad S. 2013a. Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. Adv. life sci., 1(1): 52-63.
9. Ali Q, Ali A, Ahsan M, Ali S, Khan NH, Muhammad S, Abbas HG, Nasir IA, Husnain T. 2014c. Line × Tester analysis for morpho-physiological traits of Zea mays L. seedlings. Adv. life sci., 1(4): 242-253.
10. Ali Q, Ali A, Awan MF, Tariq M, Ali S, Samiullah TR, Azam S, Din S, Ahmad M, Sharif NM, Muhammad S, Khan NH, Ahsan M, Nasir IA and Hussain T. 2014b. Combining ability analysis for various physiological, grain yield and quality traits of *Zea mays* L.*Life Sci J* 11(8s):540-551.
11. Ali, Q., A. Ali, M. Tariq, M.A. abbas, B. Sarwar, M. Ahmad, M.F. Awaan, S. Ahmad, Z.A. Nazar, F. Akram, A. Shahzad, T.R. Samiullah, I.A. Nasir, and T. Husnain 2014a. Gene Action for Various Grain and Fodder Quality Traits in *Zea Mays*. *Journal of Food and Nutrition Research*, 2(10): 704-717.
12. Ali, Q., M. Ahsan, F. Ali. S. Muhammad, M. Manzoor1, N.H. Khan, S.M.A. Basra and H.S.B. Mustafa, 2013b. Genetic advance, heritability, correlation, heterosis and heterobeltiosis for morphological traits of maize (Zea mays L). *Albanian Journal of Agricultural Sciences* 12.4 (2013): 689-698.
13. Alvi, M.B., M. Rafique, M.S. Tariq, A. Hussain. 2003. Hybris vigour of some quantitative characters in maize. Pak. J. Bio. Sci. 6(2):139-141.
14. Anonymous. 2011-12. Economic Survey of Pakistan. Govt. of Pakistan, Finance and Economic Affairs Division, Islamabad.
15. Burton, G.W. 1951. Quantitative inheritance in pearl millet (Pennisetum glaucum L.). Agron. J. 43: 409-417.
16. Desai, S.A. and R.D. Singh. 2001. Combining ability studies for some morpho-physiological and biochemical traits related to drought tolerance in maize. Indian J. Genet. Pl. Br. 60(1): 203-215.
17. Falconer, D.S. 1989. Introduction to Quantitative Genetics. 3rd Ed. Logman Scientific & Technical, Logman House, Burnt Mill, Harlow, Essex, England.
18. Grzesiak, M.T., A. Rzepka, T. Hura, K. Hura and A. Skoczowski. 2007. Changes in response to drought stress of triticale and maize genotypes differing in drought tolerance. Photosynth. 45: 280-287.
19. Khan , M.B., N Hussain and M. Iqbal. 2001. Effect of water stress on growth and yield components of maize variety YHS 202. J. Res. 12(1): 15-18.
20. Kwon, S.H. & J.H. Torrie (1964). Heritability and interrelationship of two soybean (Glycine max L.) populations. Crop Sci. 4: 196-198.
21. Mehdi, S. S. and M. Ahsan. 2000. Genetic coefficient of variation, relative expected genetic advance and inter-relationships in maize (Zea mays L.) for green fodder purposes at seedling stage. Pak. J. Bio. Sci. 11: 1890-1891.
22. Muhammad S, Shahbaz M, Iqbal M, Wahla AS, Ali Q, Shahid MTS, Tariq MS. 2013. Prevalence of different foliar and tuber diseases on different varieties of potato. Adv. life sci., 1(1): 64-70.
23. Sabbir MZ, Arshad M, Hussain B, Naveed I, Ali S, Abbasi A and Ali Q, (2014). Genotypic response of chickpea (*Cicer arietinum* L.) for resistance against gram pod borer (*Helicoverpa armigera* (Hubner))**.** Adv. life sci., 2(1): In Press.
24. Steel, R.G.D., J.H.Torrie and D.A.Dicky.1997. Principles and procedures of Statistics. A Biometrical Approach 3rd Ed. McGraw Hill Book Co. Inc. New Yark, pp: 400-428.
25. Tariq M, Ali Q, Khan A, Khan GA, Rashid B, Rahi MS, Ali, A, Nasir IA, Husnain T. (2014). Yield potential study of Capsicum annuum L. under the application of PGPR. Adv. life sci., 1(4): 202-207.
26. Vafias, B.N., C.G. Ipsilandis. 2005. Combining ability, gene action and yielding performance in maize. Asian J. Pl. Sci. Pak. 4(1):50-55.

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