*Pure Appl. Biol., 8(2): 1359-1373, June, 2019*
*http://dx.doi.org/10.19045/bspab.2019.80077*

**Research Article**

# Genetical studies of corn crop to exploit heterosis, proportional contribution and gene action at diverse water regimes

Taufiq Ullah[1], Ijaz Rasool Noorka[1*], JS (Pat) Heslop-Harrison[2], Faisal Saeed Awan[3] and Worku Negash Mhiret[4]
1. Department of Plant Breeding and Genetics, College of Agriculture, University of Sargodha-Pakistan
2. Department of Genetics and Genome Biology, University of Leicester, Leicester, LE1 7RH-United Kingdom
3. Centre of Agricultural Biochemistry and Biotechnology, University of Agriculture, Faisalabad-Pakistan
4. Department of Biology, College of Natural and Computational Sciences, University of Gondar, Gondar-Ethiopia
**Corresponding author's email:* ijazphd@yahoo.com

**Citation**
Taufiq Ullah, Ijaz Rasool Noorka, JS (Pat) Heslop-Harrison, Faisal Saeed Awan and Worku Negash Mhiret. Genetical studies of corn crop to exploit heterosis, proportional contribution and gene action at diverse water regimes. Pure and Applied Biology. Vol. 8, Issue 2, pp1359-1373. http://dx.doi.org/10.19045/bspab.2019.80077

Received: 05/11/2018 Revised: 20/02/2019 Accepted: 25/04/2019 Online First: 04/05/2019

## Abstract

The study is based on mating fashion of line × tester and its relative analysis to exploit the heterosis, proportional contribution of diverse lines, testers, their interaction and gene action in cross combinations of different corn genotypes under different water regimes. Total 12 parents comprised of eight lines and four testers; crossed to produce 32$F_1$ hybrids. Parents including their hybrids were evaluated in CRD with three water treatments under controlled conditions with three replications in two seasons. Heterosis, percent contribution of lines, testers and line × tester interaction and gene action were studied for the traits i.e. ear leaf area, number of kernel rows per ear, 100 grain weight, biological yield, vegetative dry matter and anthesis-silking interval. Variable heterosis both in magnitude and direction was observed. Both additive and non-additive gene effects have role in the control of anthesis-silking interval; whereas non-additive gene effects were observed for ear leaf area, number of kernel rows per ear, 100 grain weight, biological yield and vegetative dry matter. However100 seed weight was mainly affected by dominance effects under this study that helped for the selection of parents to be used for the development of synthetics and hybrids durable for different water regimes.

**Keywords**: Additive; Hybrid; Line × tester; Susceptible; Water stress



## Introduction

Food security in the world is challenged by increasing food demand and threatened by declining water availability. This water crisis is a severe threat for sustainable agriculture, particularly in Asia, where irrigated agriculture accounts for 90% of total diverted fresh water **[1]**. Due to rapid increase in population of developing countries, the demand for food is increasing with every passing day, and this pressure for high food demand will continue for next three coming decades.**[1]**.

There are many constraints in corn production especially in developing countries like Pakistan, including different kinds of biotic and abiotic stresses. Biotic stresses include pathogens, diseases and bacteria [2] and abiotic stresses include salinity, fluctuating heat pattern, temperature variations, high pH, metal toxicity and water stresshaving detrimental effects on plant growth and yield [3].Corn a C4 plant is an efficient user of water and highly responsive to water shortages [4]. Heterosis and combining ability is pre-requisite for developing desirable corn hybrids [5].

Combining ability is a measure of additive gene action [6] while specific combining ability (SCA) is due to genes showing non-additive effects [7]. Genetics use for the development of drought tolerant plants is an important for yield stability on global bases [8]. In conventional breeding methods, genetic variability against drought tolerance can be identified and introduced through different mating techniques to develop cultivars with good agronomic traits [9].Thus selection of parental lines is essentially based on general and specific combining ability.

Therefore a study was made to investigate different parents and their crosses under different water regimes in Line × tester analysis, proportional contribution of lines, testers and line × tester interaction, nature of gene action and direction and magnitude of heterosis to obtain reliable genetic information of grain yield and their related traits in corn breeding program. So this information helps the plant breeder to construct the breeding strategy under water stress conditions [10].

**Materials and methods**

Total 44 newly developed genotypes including 12 parents and 32 crosses were sown in the polythene bags (45 × 30cm) filled with mixture of soil (Soil, Silt and organic matter, in equal amount) having (pH 8.2 and EC.0.4) under three water treatments:

Water treatment1 T1 Eighty percent (80%) of field capacity

Water treatment2 T2 Sixty percent (60%) of field capacity

Water treatment3 T3 Forty percent (40%) of field capacity in wire-house of Department of Plant Breeding and Genetics, University College of Agriculture, Sargodha, Pakistan. Recommended agronomic, cultural and plant protection measures were kept uniform to all the three sets of experimental units except irrigation water. Insecticide was applied to control the insect attack. Two factor factorial triplicate randomized complete designs were followed. Each genotype was sown in three lines per replication per treatment in two seasons during spring and autumn seasons. Three water treatments were applied following [11].The Average maximum and minimum temperature of 100 days of Season 1& II was depicted by (Figure 1 & 2) respectively. The different traits data were recorded at maturity (Table 1).

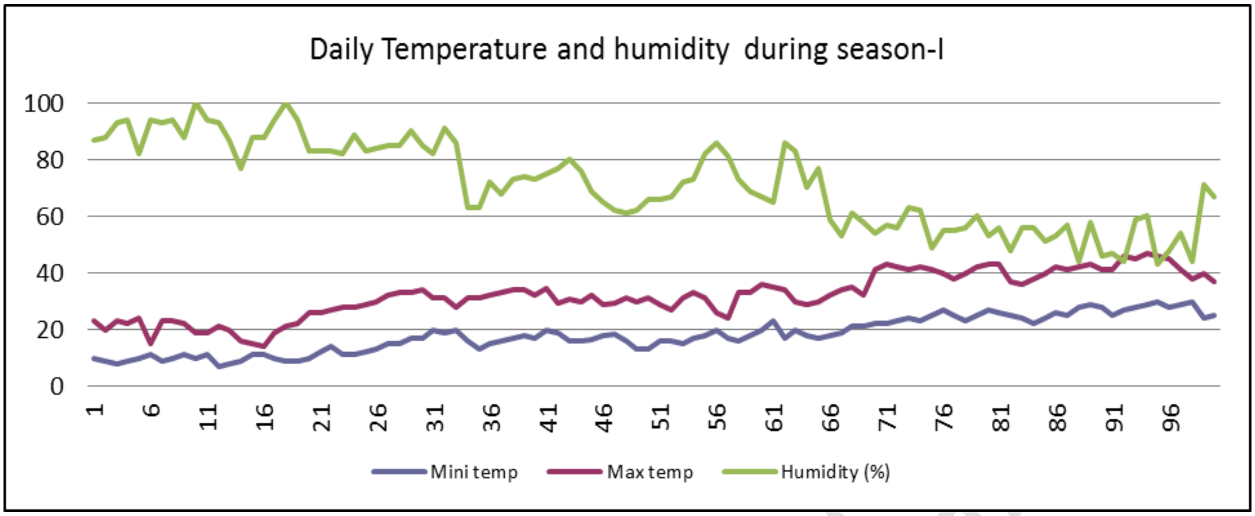


**Figure 1. Average maximum and minimum temperature of 100 days of Season 1**

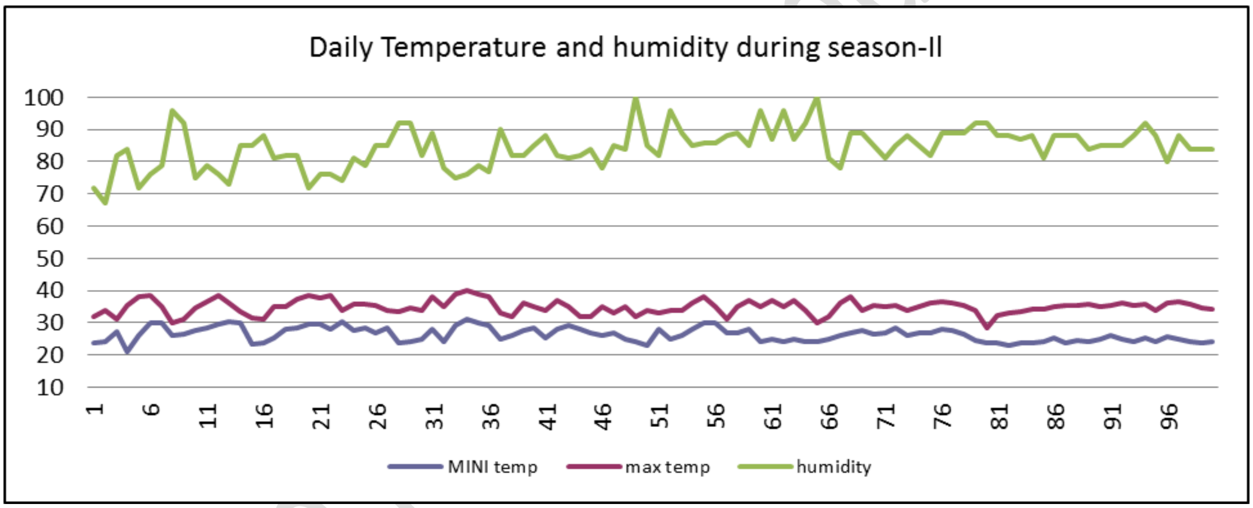


**Figure 2. Average maximum and minimum temperature of 100 days of season II**

**Table 1. The data was recorded on appropriate time for the following traits**

| | | |
|---|---|---|
| 1 | Ear Leaf Area | Five randomly selected guarded plants were measured in $cm^2$, using leaf area meter (ΔT-MK2, England) and then average was computed |
| 2 | Number of Rows per Ear | Five randomly selected guarded plants of each treatment was counted and then average was calculated. |
| 3 | 100-grain Weight | Measured in grams with an electronic balance (OHAUS-GT 4000, USA) from the bulk produce of five randomly selected plants in each treatment. |
| 4 | Biological Yield | Average weight of five randomly selected plants separately in grams |
| 5 | Vegetative Dry Matter | Five randomly selected plants in grams by using electronic balance (OHAUS-GT 4000, USA) and then average was determined |
| 6 | Anthesis-Silking Interval | Anthesis was started before the emergence of silk on the cob of the respective plants. Dates of anthesis and silking of all corn accessions were recorded. The difference between dates of anthesis-silking intervals was calculated for all the genotypes separately. |

**Statistical analysis**

The recorded data were statistically analyzed [12] and were also subjected to line × tester analysis of variance (ANOVA) as outlined by [13].

**1. Heterosis**

Heterosis over better parent was estimated as followed by [14].

T-test was calculated [15] to compare significance of heterosis.

**2. Proportional Contribution of lines, Testers and their interaction to total variance**

Contribution of lines = $\{ss(l)/ss(crosses)\}\times 100$;

Contribution of tester $\{ss(t)/ss(crosses)\}\times 100$;

Contribution of $(lxt) = \{ss\,((lxt)/ss$ (crosses)} ×100

**3. Genetic Components**

Cov H.S. (lines) = $M_l - M_l xt/rt$; Cov H.S. (tester) = $M_t - M_l xt/rl$

Cov H.S. (average) = $[l/r(2lt-l-t)][(\{(l-1)(M_l)+(t-1)(M_t)\}/(1+t-2))-M_{lxt}]$

**Results**

Analyses of variance for per cent contribution of lines, testers and lines × testers interaction and gene action for number of leaves of maize genotypes in 8x4 line × tester cross in contrasting water regimes under controlled conditions for season-I and II. (Table 2)

In season-I, heterotic manifestations in 32 corn genotypes for ear leaf area, number of kernel rows per area, 100 grain weight, biological yield, vegetative dry matter and anthesis-silking interval were measured under water treatment1, 2 and 3, (Table 3) heterosis value depicts different in magnitude and direction. Under water treatment1,Crosses DR-187 × Pak Afgoeefor ear leaf area,DR-189 × Sadaaf for number of kernels rows per ear, DR-158 × Pak Afgoeefor 100 grain weight, DR-198 × Pak Afgoee for biological yield,DR-177 × EV-6098 for vegetative dry matter and DR-198 × EV-6098for anthesis-silking had maximum positive and significant heterosis while Crosses DR-159 × Ev-1098 for ear leaf area,DR-185 × Ev-1098for number of kernels per row, DR-177 × EV-6098 and DR-177 × Pak Afgoee for 100 grain weight, DR-198 × EV-6098for biological yield,DR159 × Ev-6098 and DR-159 × Sadaaf, DR-198 × EV-1098 for anthesis-silking had minimum positive and significant heterosis whereas Crosses DR-158 × Ev-1098 for ear leaf area,DR-194 × EV-1098for number of kernel rows per ear, DR-194 × EV-1098 for 100 grain weight, DR-159 × Sadaaf for biological yield,DR-194 × Ev-6098for vegetative dry matter andDR-185 × Pak Afgoee and DR-185 × Sadaaffor anthesis-silking had maximum negative and significant heterosis while Crosses DR-159 × Sadaaffor ear leaf area, DR-198 × EV-1098for number of kernel rows per ear, DR-159 × Ev-1098 for 100 grain weight, DR-158 × Pak Afgoee for biological yield,DR-198 × Pak Afgoee for vegetative dry matter and DR-158 × Sadaaf for anthesis-silking had maximum negative and significant heterotic value. Under water treatment 2 Crosses DR-187 × Pak Afgoee for ear leaf area,DR-189 × Sadaaf for number of kernels per row, DR-159 × Ev-1098 for 100 grain weight, DR-185 × Pak Afgoee for biological yield,DR-177 × Pak Afgoee for vegetative dry matter and DR-187 × Ev-6098 for anthesis-silking interval had maximum positive and significant heterosis while Crosses DR-185 × Ev-6098for ear leaf area, DR-177 × EV-6098 for number of kernels per row, DR-189 × Pak Afgoeefor 100 grain weight, DR-198 × EV-6098 for biological yield,DR-198 × EV-6098for vegetative dry matter andDR159 × Ev-6098 for anthesis-silking interval had minimum positive and significant heterosis whereas Crosses DR-159 × Ev-1098for ear leaf area,DR-159 × Sadaaf and DR-159× Ev-6098 for number of kernels per row, DR-194 × Sadaaf for grain weight, DR-159 × Sadaaffor biological yield,DR-194 × Ev-6098 for vegetative dry matter andDR-194 × Pak Afgoee for anthesis-silkinghad maximum negative and significant heterosis while crosses DR-158 × Ev-1098 for ear leaf area,DR-187 × Ev-1098for number of kernels per row, DR-194 × Ev-6098 for 100 grain weight, DR-159 × Ev-1098 for biological yield, DR-187 × Ev-6098 for vegetative dry matter and DR-189 × Ev-1098 and DR-159 × Ev-1098 for anthesis-silking had minimum negative and significant heterosis effects. Under water treatment 3, Crosses DR-187 × PakA fgoee for ear leaf area, DR-159 × Ev-1098for 100 grain weight, DR-198 × Pak Afgoee for biological yield,DR-185 × Pak Afgoee for vegetative dry matter and DR-177 × Sadaaf for anthesis-silking interval had maximum positive and significant heterosis while crosses DR-159 × Sadaaf for ear leaf area, DR-189 × Sadaaf for number of kernel rows per ear, DR-159 × Sadaaf for 100 grain weight, DR-194 × Ev-6098 for 100 grain weight, DR-198 × EV-6098 for biological yield,DR-194 × Ev-6098 for vegetative dry matter and DR-177 × Ev-6098, DR-158 × Ev-6098, DR-189 × Pak Afgoee and DR-159 × Sadaaf for anthesis-silking interval had minimum positive and significant heterosis whereas Crosses DR-159 × Ev-1098 for flag leaf area, DR-159× Ev-6098for number of kernels rows per ear, DR-198 × PakAfgoee for 100 grain weight, DR-159 × Sadaaf biological yield,DR-189 × Pak Afgoee for vegetative dry matter andDR-185 × Sadaaf for anthesis-silking interval had maximum negative and significant heterosis while Crosses DR-158 × Ev-1098for ear leaf area,DR-177 × Sadaaf for number of kernels rows per ear, DR-177 × EV-6098 for 100 grain weight, DR-158 × Pak Afgoee for biological yield,DR-194 × Pak Afgoee for vegetative dry matter andDR-177 × Pak Afgoee, DR-194 × Ev-6098, DR-185 × Pak Afgoee for anthesis-silking interval had minimum negative and significant heterosis.

In season-II under water treatment 1, (Table 3) The crosses DR-187 × Pak Afgoee for ear leaf area, DR-158 × Pak Afgoee for 100 grain weight, DR-185 × Ev-6098 for biological yield andDR-177 × Ev-1098, DR-194 × EV-1098anthesis-silking interval had maximum positive and significant heterosis while Crosses DR-159 × Ev-6098for ear leaf area,DR-177 × EV-6098 for number of kernels per ear, DR-158 × Ev-1098 for 100 grain weight, DR-194 × Ev-6098for biological yield andDR-177 × EV-6098, DR-185 × Ev-1098 anthesis-silking interval had minimum positive and significant heterosis whereas Crosses DR-185 × Sadaaf for ear leaf area,DR-159 × Ev-1098for number of kernel rows per ear, DR-198 × EV-1098for 100 grain weight, DR-158 × Ev-1098for biological yield,DR-185 × Pak Afgoeefor vegetative dry matter andDR-159 × Pak Afgoee for anthesis-silking interval had maximum negative and significant heterosis whereas Crosses DR-194 × Sadaaf for ear leaf area,DR-189 × Pak Afgoee,DR-189 × Ev-1098for number of kernel rows per ear, DR-189 × Ev-1098 for 100 grain weight, DR-185 × Sadaaf for biological yield, DR-187×Ev-6098for vegetative dry matter and DR-177 × Sadaaf,DR-198 × Sadaaf for anthesis-silking interval had minimum negative and significant heterosis. Under water treatment 2, Crosses DR-198 × Sadaaf for ear leaf area, DR-159 × Ev-1098for 100 grain weight,DR-185 × Ev-6098for biological yield, DR-159 × Ev-6098 for vegetative dry matter and DR-189 × Ev-1098 for anthesis-silking intervalhad maximum positive and significant heterosiswhile Crosses DR-159 × Ev-1098, DR-159 × Ev-6098for ear leaf area, DR-159 × Sadaaffor 100 grain weight, DR-189 × Ev-1098 for biological yield, DR-189 × Ev-6098for vegetative dry matter andDR-177×Pak Afgoee, DR-189× Sadaaf for anthesis-silkinginterval had minimum positive and significant heterosisWhereas Crosses DR-159 × Sadaaf for ear leafarea,DR-159 × Ev-1098for number of kernel rows per ear, DR-194 × EV-1098for 100 grain weight,DR-158 × Ev-1098for biological yield,DR-187 × Pak Afgoee for vegetative dry matter,DR-159 × Ev-1098 anthesis-silking interval had maximum negative and significant heterosis while Crosses DR-159 × Pak Afgoee for ear leaf area,DR-189 × Ev-1098for number of kernel rows per ear, DR-198 × Pak Afgoee for 100 grain weight, DR-185 × Sadaaf for biological yield,DR-159 × Ev-1098for vegetative dry matter andDR-158 × Pak Afgoee,DR-158 × Sadaaf foranthesis-silking interval had minimum negative and significant heterosis. Under water treatment 3, Crosses DR-177 × Pak Afgoee for ear leaf area, DR-159 × Ev-1098 for 100 grain weight, DR-185 × Ev-6098for biological yield andDR-194 × EV-1098for anthesis-silking interval had maximum positive and significant heterosis while Crosses DR-159 × Ev-6098for ear leaf area,DR-177 × EV-6098for number of kernel rows per ear, DR-158 × Ev-1098 for 100 grain weight, DR-194 × Ev-6098for biological yieldandDR-198 × Ev-6098, DR-158 × Sadaaf and DR-189 × Sadaaf for anthesis-silking interval had minimum positive and significant heterosis whereas Crosses DR-159 × Ev-1098for ear leaf area,DR-158 × Ev-1098for number of kernel rows per ear,DR-198 × Pak Afgoee for 100 grain weight, DR-158 × Ev-1098for biological yield andDR-187 × Ev-1098 for anthesis-silking interval had maximum negative and significant heterosis while Crosses DR-158 × Ev-1098 for ear leaf area,DR-185 × Sadaaf for number of kernel rows per ear, DR-177 × EV-6098 for 100 grain weight, DR-185 × Sadaaf for biological yield and DR-158 × Pak Afgoee for anthesis-silkinginterval had minimum negative and significant heterosis.

Under water treatment 1 in season-I and II (Table 4), proportional contribution of lines for the traits ear leaf area, lines for number of kernel rows per ear, Line × tester interaction for 100 grain weight Lines for biological yield except in season-II where Line × tester interaction for the biological yield, Lines for vegetative dry matter except in season-II where Line × tester interaction for vegetative dry matter and line × tester interaction for anthesis-silking interval and in season-II, lines for anthesis-silking interval contribute maximum in the total phenotype.

Under water treatment 2 and 3in season-I, proportional contribution of lines for ear leaf area, lines for number of kernel rows per ear, Line × tester interaction for 100 grain weight, Line × tester interaction for biological yield, lines for vegetative dry matter except in water treatment3, Line × tester interaction for vegetative dry matter and Line × tester interaction for anthesis-silking interval had more contribution under water treatment 2 and 3. In season-II, proportional contribution of lines for ear leaf area, Line × tester interaction for number of kernel rows per ear, Line × tester interaction for 100 grain weight, Line × tester interaction for biological yield, lines for vegetative dry matter and lines for anthesis-silking interval shared maximum in total phenotypic variance.

Dominance variance, additive variance and potence ratio for the traits ear leaf area,100 grain weight, biological yield, vegetative dry matter and anthesis-silking interval (Table 4) under three water treatments in season-I and II, over dominancewas observed for all these traits under these water conditions in both seasons except for anthesis-silking interval in season-II where over dominance was observed under water treatment 1and 2 but partial dominance observed for anthesis-silking under water treatment 3.

**Table 2 . Analyses of variance, for per cent contribution of lines, testers and lines × testers interaction and gene action for number of leaves of maize genotypes in 8x4 line × tester cross in contrasting water regimes under controlled conditions for season-Iand II**

| | | Season-I | | | Season-II | | |
|---|---|---|---|---|---|---|---|
| **S.O.V** | **d.f** | **Normal** | **WS-I** | **WS-II** | **Normal** | **WS-I** | **WS-II** |
| Genotype | 43 | 4.85** | 2.42** | 2.58** | 3.81** | 4.94** | 2.66** |
| Parents | 11 | 2.51** | 2.16** | 3.79** | 6.18** | 9.35** | 5.66** |
| Crosses | 31 | 5.30** | 2.24** | 2.02** | 2.66** | 2.95** | 1.49** |
| Parents Vs Crosses | 1 | 16.55** | 11.10** | 6.73** | 13.14** | 18.03** | 5.67** |
| Lines | 7 | 8.68 | 3.25 | 2.99** | 7.31** | 7.33** | 3.83** |
| Testers | 3 | 0.79 | 0.34 | 0.13 | 0.25 | 1.01 | 0.74 |
| Line × tester | 21 | 4.82** | 2.17** | 1.97** | 1.46** | 1.76** | 0.82** |
| Residual | 86 | 0.65 | 0.25 | 0.53 | 0.48 | 0.32 | 0.41 |
| Contribution percentage | | **Normal** | **WS-I** | **WS-II** | **Normal** | **WS-I** | **WS-II** |
| Lines | | 36.96 | 32.82 | 33.47 | 62.02 | 56.15 | 57.88 |
| Testers | | 1.44 | 1.48 | 0.60 | 0.91 | 3.32 | 4.77 |
| Line × tester | | 61.60 | 65.70 | 65.94 | 37.07 | 40.54 | 37.35 |
| Dominance б | | 1.39 | 0.64 | 0.48 | 0.33 | 0.48 | 0.14 |
| Additive б | | 0.01 | 0.00 | 0.00 | 0.02 | 0.01 | 0.01 |
| Potence ratio (Degree of dominance) | | 481.22 | 1577.35 | 1480.39 | 44.89 | 67.68 | 34.16 |

**Table 3. Heterosis effects in 32 corn genotypes for ear leaf area, number of kernel rows per ear, 100 grain weight, biological yield, vegetative dry matter and anthesis-silking interval in contrasting water regimes under controlled conditions in season-I and II**

| **Hybrids** | | Season-I | | | | | | Season-II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **E.L.A** | **R.N** | **100 g.wt.** | **B.Y** | **V.D.M** | **ASI** | **E.L.A** | **R.N** | **100 g.wt.** | **B.Y** | **V.D.M** | **ASI** |
| DR-187 × Pak Afgoee | T1 | 27.94 | -15.79 | -4.92 | -18.29 | -6.98 | -22.73 | 27.40 | -16.67 | -4.20 | -18.08 | -7.84 | -11.76 |
| | T2 | 32.93 | -17.39 | -12.44 | -11.64 | -13.73 | -13.33 | 18.8 | -17.39 | -4.53 | -18.36 | -7.95 | -8.00 |
| | T3 | 37.98 | -22.00 | -22.99 | -19.91 | -12.78 | 7.69 | 21.43 | -21.74 | -23.24 | -18.64 | -12.24 | 1.79 |
| DR-187 × Sadaaf | T1 | 17.04 | -14.56 | -20.49 | -29.67 | 11.05 | -15.22 | 16.86 | -4.35 | -18.49 | -28.29 | 9.39 | -12.5 |
| | T2 | 20.99 | -4.55 | -22.49 | -28.46 | 3.75 | -4.26 | 17.49 | -9.09 | -7.79 | -28.3 | 4.01 | -10.87 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T3 | 25.38 | -7.5 | -25.29 | -31.51 | -1.61 | -13.79 | 9.63 | -4.76 | -25.70 | -28.31 | -1.65 | -22.22 |
| DR-187 × Ev-1098 | T1 | 13.33 | -22.94 | -9.84 | -17.02 | -2.28 | -11.11 | 13.62 | -4.17 | -6.72 | -22.04 | -4.75 | -26.67 |
| | T2 | 14.47 | -4.35 | -13.88 | -15.11 | -8.79 | -8.16 | 15.25 | -4.35 | -4.50 | -23.92 | 0.85 | -2.38 |
| | T3 | 15.72 | -4.15 | -19.54 | -19.85 | -5.14 | -11.54 | 8.79 | -8.34 | -14.68 | -25.84 | -0.55 | -38.89 |
| DR-187 × EV-6098 | T1 | 15.78 | -20.81 | -10.66 | -23.15 | -0.27 | 21.62 | 19.88 | -9.52 | -8.40 | -24.93 | -6.33 | -26.67 |
| | T2 | 17.62 | -10.00 | -18.18 | -24.86 | -2.62 | 8.89 | 19.01 | -4.18 | -6.13 | -24.8 | -3.58 | -11.32 |
| | T3 | 19.52 | -3.72 | -28.74 | -24.38 | -6.83 | -3.85 | 21.1 | -4.39 | -28.4 | -24.67 | -6.92 | -33.33 |
| DR-177 × Pak Afgoee | T1 | 22.62 | -20.88 | 0.00 | -20.75 | -1.69 | -25 | 22.67 | -16.67 | 0.88 | -15.41 | -7.32 | -11.76 |
| | T2 | 29.12 | -17.39 | -13.3 | -16.31 | -2.42 | -18.75 | 15.68 | -15.96 | -3.45 | -15.87 | -4.11 | 0.00 |
| | T3 | 33.92 | -22.73 | -30.68 | -25.62 | -2.54 | -7.69 | 30.64 | -20.3 | -26.22 | -16.33 | -1.96 | -8.93 |
| DR-177 × Sadaaf | T1 | 4.62 | -25.00 | 5.22 | 6.38 | 10.52 | -21.74 | 4.25 | -21.74 | 5.31 | -26.46 | 52.92 | -6.25 |
| | T2 | 7.14 | -13.64 | -10.10 | 9.28 | -11.47 | -18.75 | 8.26 | -16.68 | -3.28 | -28.02 | 29.58 | 2.17 |
| | T3 | 7.19 | -20.00 | -30.11 | 5.23 | -1.22 | 48.28 | 5.33 | -18.26 | -26.68 | -29.59 | 2.82 | 1.85 |
| DR-177 × Ev-1098 | T1 | 12.32 | -19.63 | -9.57 | -20.23 | 6.11 | -13.33 | 11.35 | -20.83 | -7.96 | 8.96 | -6.78 | 18.18 |
| | T2 | 11.26 | -21.74 | -17.49 | -14.51 | -0.62 | -10.2 | 12.1 | -15.48 | -6.33 | 9.12 | -2.11 | 9.52 |
| | T3 | 9.54 | -12.53 | -27.84 | -23.09 | -1.31 | 19.23 | 14.31 | -15.93 | -27.15 | -13.68 | -1.21 | 16.67 |
| DR-177 × EV-6098 | T1 | 9.18 | -10.44 | 13.14 | 19.3 | -2.43 | -21.95 | 7.53 | 0.00 | 14.78 | -24.27 | 42.96 | 7.14 |
| | T2 | 8.84 | 0.00 | -8.87 | 6.25 | 10.45 | -31.25 | 14.39 | 0.55 | -5.37 | -24.75 | 52.75 | -11.32 |
| | T3 | 8.28 | 1.83 | -15.91 | 17.36 | 55.43 | 0.00 | 13.42 | 0.00 | -10.9 | -25.25 | 56.73 | 1.85 |
| DR-198 × Pak Afgoee | T1 | 17.12 | -8.38 | 19.81 | 29.52 | -6.18 | -38.64 | 16.99 | -12.5 | 20.00 | -22.84 | 52.31 | -11.76 |
| | T2 | 19.45 | -13.04 | -2.76 | -1.15 | 1.09 | -31.25 | 20.16 | -11.11 | -1.95 | -23.73 | 29.37 | -8.00 |
| | T3 | 22.01 | -19.73 | -34.67 | 28.1 | -5.36 | 21.43 | 24.1 | -16.67 | -37.92 | -24.63 | -3.49 | -10.53 |
| DR-198 × Sadaaf | T1 | 21.72 | -7.13 | -2.83 | -11.00 | 5.03 | -41.3 | 21.05 | -13.04 | -2.86 | -20.9 | 11.05 | -6.25 |
| | T2 | 23.96 | -13.64 | 1.66 | -17.25 | 5.58 | -18.75 | 22.63 | -13.14 | 0.97 | -21.09 | 10.81 | -12.00 |
| | T3 | 27.13 | -19.18 | 8.00 | -14.98 | -2.18 | 44.83 | 25.99 | -11.14 | 7.05 | -21.28 | 10.57 | -10.53 |
| DR-198 × EV-1098 | T1 | 18.91 | -8.33 | 1.77 | 20.26 | -1.06 | 0.00 | 18.42 | -26.00 | 2.70 | 20.91 | -9.92 | -31.82 |
| | T2 | 19.89 | -21.74 | 16.85 | 17.19 | 2.22 | -2.04 | 20.97 | -20.74 | 4.52 | 20.47 | -1.51 | -16 |
| | T3 | 19.18 | -24.18 | 28.67 | 21.47 | -0.21 | 7.14 | 17.58 | -21.23 | 27.15 | 20.03 | -0.39 | -21.05 |
| DR-198 × EV-6098 | T1 | 14.5 | -14.63 | -7.63 | 5.84 | 10.41 | 7.14 | 13.35 | 4.35 | -5.22 | 17.96 | -9.13 | -4.55 |
| | T2 | 16.66 | 4.55 | 8.29 | 4.96 | 10.89 | 6.25 | 16.95 | 4.55 | 2.14 | 17.83 | -3.01 | -13.21 |
| | T3 | 19.14 | 1.68 | 16.00 | 5.90 | -1.73 | 14.29 | 19.23 | 4.76 | 8.34 | 17.69 | -2.76 | 0.00 |
| DR-194 × Pak Afgoee | T1 | 9.55 | -29.61 | -4.51 | 7.77 | -2.65 | -38.64 | 8.53 | -16.67 | -4.65 | 15.06 | -8.32 | -9.8 |
| | T2 | 13.55 | -17.39 | -9.78 | 3.67 | 4.48 | -40.00 | 5.73 | -15.52 | -3.22 | 15.79 | -6.19 | -2.00 |
| | T3 | 18.84 | -20.48 | -17.39 | 7.76 | -1.73 | 7.69 | 19.17 | -20.74 | -18.77 | 16.54 | -3.83 | -14.29 |
| | T1 | 2.48 | -28.56 | -24.81 | -30.8 | 8.17 | -41.3 | -0.17 | -13.04 | -21.71 | -18.71 | -10.28 | -6.25 |

http://dx.doi.org/10.19045/bspab.2019.80077

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DR-194 × Sadaaf | T2 | 5.54 | -13.64 | -24.44 | -30.51 | 9.68 | -23.4 | 8.27 | -12.59 | -8.33 | -18.41 | -7.43 | 2.17 |
| | T3 | 10.53 | -12.53 | -23.91 | -33.64 | -4.45 | -10.34 | 5.24 | -12.19 | -19.13 | -18.1 | -4.26 | -5.56 |
| DR-194 × EV-1098 | T1 | 11.68 | -30.22 | -26.32 | -34.38 | 10.81 | 2.22 | 10.21 | -20.83 | -24.03 | 9.09 | -36.32 | 18.18 |
| | T2 | 10.71 | -13.04 | -22.67 | -33.56 | 34.71 | -2.04 | 16.23 | -21.26 | -8.64 | 9.19 | -20.24 | 9.52 |
| | T3 | 9.13 | -10.00 | -17.39 | -35.26 | -1.15 | -11.54 | 14.94 | -21.98 | -14.4 | 9.29 | -3.56 | 21.43 |
| DR-194 × Ev-6098 | T1 | 20.76 | -18.50 | -10.53 | -28.93 | 5.72 | -14.29 | 18.55 | -21.74 | -9.30 | 7.37 | -33.13 | 0.00 |
| | T2 | 22.41 | -13.64 | -6.22 | -26.17 | 22.53 | -6.67 | 21.83 | -20.7 | -2.31 | 7.98 | -18.27 | -5.66 |
| | T3 | 25.15 | -18.33 | 0.00 | -28.43 | -0.15 | -7.69 | 22.89 | -16.69 | -3.46 | 8.61 | -3.24 | -11.11 |
| DR-158 × Pak Afgoee | T1 | 12.16 | -7.13 | 20.39 | -9.04 | -2.87 | -25.00 | 13.28 | -25.00 | 20.39 | 11.76 | -20.84 | -17.65 |
| | T2 | 16.9 | -21.74 | 29.61 | -6.84 | 10.11 | -6.67 | 9.46 | -24.65 | 9.99 | 12.25 | -9.58 | -8.00 |
| | T3 | 21.16 | -24.27 | 42.11 | -7.6 | 1.14 | 11.54 | 23.77 | -25.61 | 43.13 | 12.75 | -1.67 | -5.26 |
| DR-158 × Sadaaf | T1 | 1.81 | -11.06 | 2.91 | -49.89 | 67.54 | -2.17 | 1.56 | -20.83 | 2.91 | -27.77 | 16.67 | -4.17 |
| | T2 | 3.27 | -18.18 | 5.59 | -33.73 | 17.31 | -4.26 | 0.40 | -19.8 | 2.66 | -27.33 | 6.04 | -6.38 |
| | T3 | 3.02 | -17.53 | 9.21 | -50.84 | -4.3 | -10.34 | 6.69 | -20.7 | 9.37 | -26.88 | -5.11 | 0.00 |
| DR-158 × Ev-1098 | T1 | -2.31 | -6.94 | 7.08 | -42.09 | 46.54 | -40.00 | -2.39 | -16.67 | 9.46 | -43.45 | 38.6 | -37.5 |
| | T2 | -3.43 | -17.39 | 12.01 | -43.04 | 22.99 | -38.78 | 1.54 | -20.54 | 3.52 | -43.02 | 22.79 | -6.38 |
| | T3 | -5.26 | -14.18 | 4.61 | -44.09 | -4.26 | -19.23 | -1.97 | -40.41 | 5.77 | -42.59 | -4.8 | -36.84 |
| DR-158 × Ev-6098 | T1 | 8.48 | -17.38 | -20.34 | -16.5 | -0.56 | -23.08 | 7.52 | -4.17 | -16.96 | -29.12 | 8.78 | -31.25 |
| | T2 | 8.34 | 6.07 | -9.50 | -22.81 | -0.63 | -17.78 | 10.69 | -4.35 | -3.27 | -29.38 | 4.66 | -11.32 |
| | T3 | 7.74 | -4.15 | -10.53 | -18.28 | -4.94 | 0.00 | 12.59 | -4.05 | -9.12 | -29.63 | -5.37 | -26.32 |
| DR-185 × Pak Afgoee | T1 | 6.82 | -22.13 | 6.48 | 23.18 | -4.71 | -42.55 | 6.25 | -9.34 | 10.00 | -26.56 | 60.76 | -23.53 |
| | T2 | 10.37 | -8.70 | -1.22 | 26.14 | -22.53 | -28.26 | 5.37 | -8.22 | -0.09 | -26.41 | 31.11 | -16.00 |
| | T3 | 16.85 | -16.68 | -16.07 | 20.29 | -1.79 | -7.69 | 14.01 | -12.33 | -13.31 | -26.26 | -3.49 | -19.64 |
| DR-185 × Sadaaf | T1 | 1.00 | -21.00 | -16.67 | -12.85 | -4.93 | -42.55 | -1.6 | -8.70 | -14.29 | -7.95 | -13.69 | -43.75 |
| | T2 | 3.42 | -9.09 | 2.44 | -14.85 | 3.67 | -29.79 | 3.39 | -9.09 | -6.26 | -7.58 | -10.00 | -10.87 |
| | T3 | 7.79 | -10.00 | 39.29 | -15.88 | -2.29 | -31.03 | 0.22 | -7.95 | -4.86 | -7.21 | -5.99 | -27.78 |
| DR-185 × Ev-1098 | T1 | 7.46 | 2.06 | -6.19 | -10.99 | -4.32 | -4.26 | 8.25 | -20.83 | -4.50 | -28.79 | 13.5 | 7.14 |
| | T2 | 6.97 | -17.39 | -9.76 | -11.29 | -12.81 | -8.16 | 6.32 | -21.02 | -2.77 | -28.4 | 14.48 | 16.67 |
| | T3 | 6.19 | -11.70 | -25.00 | -12.6 | -3.47 | -19.23 | 12.84 | -16.68 | -29.85 | -28.01 | 10.66 | -5.56 |
| DR-185 × Ev-6098 | T1 | 2.07 | -4.17 | 1.69 | 20.72 | -0.45 | -4.26 | -0.36 | -4.76 | 4.35 | 23.69 | -7.33 | -7.14 |
| | T2 | 2.05 | -5.00 | -0.91 | 23.22 | -1.30 | -2.17 | 6.34 | -7.95 | -0.44 | 23.91 | -2.53 | -11.32 |
| | T3 | 2.04 | -8.81 | -21.43 | 21.61 | -0.39 | -19.23 | 4.34 | -3.33 | -22.03 | 24.14 | -1.64 | -16.67 |
| DR-189 × Pak Afgoee | T1 | 7.46 | -4.88 | -7.96 | -19.21 | -4.07 | -11.36 | 5.99 | -8.33 | -6.76 | -11.59 | -9.48 | -11.76 |
| | T2 | 11.11 | -8.7 | 7.36 | -17.2 | 3.20 | -2.17 | 8.18 | -8.70 | 2.68 | -11.15 | -5.74 | 4.00 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T3 | 17.36 | -12.14 | 42.00 | -17.43 | 0.33 | 0.00 | 14.24 | -11.61 | 46.46 | -10.71 | -2.91 | -8.93 |
| DR-189 × Sadaaf | T1 | 8.67 | 5.78 | -8.85 | -21.32 | 1.98 | -2.17 | 6.03 | 4.35 | -5.86 | -19.60 | -1.53 | -8.33 |
| | T2 | 11.99 | 4.55 | -2.45 | -16.4 | -3.92 | -4.26 | 10.47 | 4.55 | -0.93 | -18.99 | -3.98 | 0.00 |
| | T3 | 17.94 | 0.00 | 12.00 | -21.12 | -2.30 | -20.69 | 11.44 | 4.76 | 15.32 | -18.36 | -6.55 | 0.00 |
| DR-189 × Ev-1098 | T1 | 11.00 | -8.91 | -5.31 | -24.91 | 48.76 | 6.67 | 10.15 | -8.33 | -3.60 | -15.59 | 25.89 | 0.00 |
| | T2 | 9.62 | -8.7 | 0.61 | -20.99 | 19.63 | -6.12 | 10.88 | -7.98 | -0.34 | 4.96 | 10.87 | 18.18 |
| | T3 | 7.37 | -5.00 | 14.00 | -24.63 | -10.7 | -30.77 | 13.45 | -8.59 | 14.86 | -16.5 | -11.74 | -6.67 |
| DR-189 × Ev-6098 | T1 | 7.71 | -7.26 | -6.78 | -41.51 | 38.81 | -4.55 | 6.63 | -4.76 | -4.35 | 17.91 | -35.17 | 14.29 |
| | T2 | 16.24 | -5.00 | 29.91 | -41.12 | 68.34 | -4.35 | 7.37 | -2.78 | 8.93 | 18.09 | -15.18 | -11.32 |
| | T3 | 30.39 | -5.56 | 110.00 | -42.67 | 1.01 | -3.85 | 18.54 | -29.26 | 112.39 | 18.29 | -1.42 | -1.85 |
| DR-159 × Pak Afgoee | T1 | 0.15 | -23.63 | -4.24 | -47.59 | 42.78 | 4.55 | -0.66 | -23.08 | -4.22 | -29.00 | 4.21 | -35.29 |
| | T2 | 3.79 | -20.00 | 15.19 | -44.78 | 30.04 | -6.67 | -0.24 | -23.56 | 3.63 | -28.15 | -4.24 | -14.00 |
| | T3 | 10.44 | -15.95 | 64.29 | -49.48 | -3.61 | -25.00 | 9.24 | -15.72 | 63.25 | -27.27 | -7.93 | -35.00 |
| DR-159 × Sadaaf | T1 | -1.25 | -19 | -9.32 | -61.27 | 174.05 | 0.00 | -0.99 | -29.74 | -9.28 | -18.19 | 28.98 | -20.83 |
| | T2 | 0.80 | -28.00 | 25.32 | -58.8 | 126.68 | 2.13 | -0.57 | -31.08 | 6.93 | -18.19 | -0.82 | 2.17 |
| | T3 | 4.50 | -26.54 | 97.83 | -65.54 | -3.11 | 0.00 | 3.14 | -25.37 | 95.47 | -18.36 | -4.92 | -18.33 |
| DR-159 × Ev-1098 | T1 | 1.25 | 1.45 | -3.39 | -16.51 | -10.04 | 2.22 | 0.50 | -30.77 | -5.06 | 14.84 | -37.21 | -13.04 |
| | T2 | -82.67 | -24.00 | 40.25 | -16.62 | 13.98 | -6.12 | 2.04 | -31.34 | 10.90 | 14.87 | -16.17 | 6.82 |
| | T3 | -26.06 | -27.29 | 136.96 | -17.82 | -0.69 | -10.71 | -6.50 | -29.00 | 141.33 | 14.9 | -2.23 | -25.00 |
| DR-159 × Ev-6098 | T1 | 3.10 | -4.59 | -0.85 | -10.9 | -11.54 | 2.78 | 2.02 | -26.92 | -1.69 | -20.52 | -4.72 | -21.74 |
| | T2 | -79.81 | -28.00 | 24.47 | -5.8 | -16.87 | 0.00 | 2.04 | -27.34 | 8.20 | -19.92 | -0.16 | -16.98 |
| | T3 | 1.15 | -31.83 | 87.37 | -10.73 | -2.19 | -7.14 | 1.36 | -26.09 | 107.62 | -19.3 | -5.24 | -25.00 |

T1: watertreatment 1, T2: water treatment2, T3: water treatment 3,E.L.A: ear leaf area, R.N: number of kernel rows per ear, 100 g.wt:100 grain weight, B.Y: biological yield, V.D.M: vegetative dry matter and ASI: anthesis-silking interval

**Table 4. Per cent contribution of lines, testers and line × tester interaction and gene action for ear leaf area, number of kernel rows per ear, 100 grain weight, biological yield, vegetative dry matter and anthesis-silking interval of corn genotypes under controlled conditions for season-I and II**

| Contribution percentage | | Season-I | | | | | | Season-II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | E.L.A | R.N. | 100 G.wt. | B.Y. | V.D.M | ASI | E.L.A | R.N. | 100 G.wt. | B.Y. | V.D.M | ASI |
| Lines | T1 | 62.75 | 34.63 | 13.45 | 43.97 | 54.1 | 19.35 | 61.76 | 32.03 | 12.62 | 25.98 | 31.22 | 48.1 |
| | T2 | 63.2 | 46.14 | 39.24 | 41.26 | 52.43 | 16.56 | 54.96 | 35.79 | 41.72 | 26.58 | 59.55 | 44.82 |
| | T3 | 57.49 | 34.72 | 40.66 | 42.07 | 38.3 | 4.62 | 52.74 | 32.47 | 46.53 | 27.21 | 51.9 | 67.66 |

*http://dx.doi.org/10.19045/bspab.2019.80077*

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Testers | T1 | 10.46 | 2.81 | 28.54 | 13.61 | 8.83 | 24.21 | 12.34 | 2.66 | 28.45 | 9.28 | 4.42 | 18.33 |
| | T2 | 11 | 9.16 | 5.01 | 10.59 | 11.86 | 0.97 | 11.72 | 1.92 | 6.94 | 9.11 | 10.43 | 26.14 |
| | T3 | 11.7 | 0.66 | 3.5 | 14.45 | 9.18 | 0.71 | 6.18 | 3.71 | 4.24 | 8.93 | 11.77 | 9.26 |
| Line × tester | T1 | 26.79 | 62.55 | 58.01 | 42.42 | 37.07 | 56.44 | 25.9 | 65.31 | 58.93 | 64.74 | 64.36 | 33.57 |
| | T2 | 25.81 | 44.7 | 55.75 | 48.15 | 35.72 | 82.46 | 33.32 | 62.3 | 51.34 | 64.31 | 30.02 | 29.03 |
| | T3 | 30.81 | 64.62 | 55.84 | 43.49 | 52.52 | 94.67 | 41.08 | 63.82 | 49.23 | 63.86 | 36.33 | 23.08 |
| Dominance б | T1 | 701.43 | 1.34 | 9.35 | 9095.26 | 23.67 | 0.16 | 702.75 | 1.07 | 8.43 | 7466.74 | 76.16 | 0.3 |
| | T2 | 571.62 | 1.22 | 8.74 | 7243.1 | 16.72 | 0.99 | 461.9 | 0.82 | 8.79 | 7353.42 | 22.71 | -0.07 |
| | T3 | 642.83 | 0.5 | 26.84 | 8894.32 | 38.07 | 3.07 | 574.36 | 0.74 | 24.26 | 7248.89 | 7.41 | 0.02 |
| Additive б | T1 | 19.59 | 0.02 | 0.03 | 98.04 | 0.42 | 0.01 | 21.76 | 0.01 | 0.02 | 6.24 | 0.08 | 0.06 |
| | T2 | 17.1 | 0.01 | 0.04 | 54.03 | 0.31 | -0.03 | 9.71 | 0.02 | 0.06 | 7.08 | 0.55 | 0.02 |
| | T3 | 14.71 | 0.01 | 0.11 | 89.52 | 0.22 | -0.16 | 9.06 | 0.01 | 0.18 | 7.95 | 0.14 | 0.09 |
| Potence ratio (Degree of dominance) | T1 | 35.81 | 588.13 | 318.33 | 92.77 | 56.42 | 28.19 | 32.29 | 1184.45 | 356.13 | 1195.82 | 940.95 | 5.4 |
| | T2 | 33.44 | 160.37 | 232.44 | 134.07 | 53.79 | -38.23 | 47.55 | 467.48 | 158.44 | 1039.22 | 41.03 | -4.44 |
| | T3 | 43.71 | 795.91 | 243.08 | 99.36 | 169.71 | -19.07 | 63.37 | 711.15 | 137.64 | 911.41 | 53.56 | 0.23 |

T1: watertreatment 1, T2: water treatment2, T3: water treatment 3,Dominance б: Dominance Variance, Additive б: Additive variance,E.L.A: ear leaf area, R.N: number of kernel rows per ear, 100 G.wt:100 grain weight, B.Y: biological yield, V.D.M: vegetative dry matter and ASI: anthesis-silking interval

## Discussion

In cereals, photosynthesis contribution of flag leafv aries from 30 to 50% of the assimilates for grain yield [16] and initiation of grain filling coincides with the onset of senescence, therefore photosynthesis in the flag leaf and rate of senescence are most important factors for determining grain yield [17].It is generally accepted that genotypes that are enable to sustain photosynthesis in the flag leaf for a longer time tend to yield more. The reduction in yield was more severe when the stress occurred suddenly rather than gradually and at early stages of grain filling rather than at later stages [18].With the increase in water stress, flag leaf area reduced and this is the first attempt of any plant to save moisture loss from its body. In the present study, different corn genotypes were studied to know the effect of flag leaf on grain yield. A significant variability for leaf area under low water stress was seen while the biomass accumulation and drought avoidance results in reduction of water transpiration because assimilation of photosynthesis is totally depend on leaf and stomatal size which increase the water use[19].

Water stress at flowering reduces the number of kernels and kernel rows per ear but at the grain filling it reduces the kernel size [20]. With the increase of water stress in corn, results in reduction of grain yield. The similar results were also reported by independent work of [21].

Biological yield and vegetative dry matter are the major component of yield and are directly relates to the amount of water use [19] these are the products of photosynthesis. Underwater shortage, Photosynthesis can decrease and results in poor production of biomass. However biomass production can be enhanced by increasing the soil moisture uptake, results decrease in soil moisture through evaporation [19]. Similar results are concluded by earlier research works of [22] who reported that corngrain yield, were under the control of non-additive (SCA effect) type of gene action.

Flowering is the critical stage of plant that has greater impact on yield production, very sensitive to low water stress in corn [23]. Silk is the female part of the plant played very important role in pollination and finally results in fertilization. With the increase in water stress at the reproductive stage slow down the silk growth rate, decreases the time of opening the silk to pollinating anther in corn. Slow growth rate of silks increases the anthesis-silking interval, decreases the chancing of pollination and seed setting. For successful seed setting, time of pollen shading must be coinciding with the silk exertion [24]. The time of anthesis is largely independent of water stress and alleles for leaf elongation rate confirmed a low anthesis-silking interval [25]. This open pollinated variety could be regarded as the most desirable parent for this trait. The similar report is made by [26] who independently reported that GCA effects were significant for anthesis-silking interval and additive gene action played a significant role in the inheritance of the character.

For the evaluation of developed hybrids, evaluation and selection of parents was one of the main objects of this study. Combining abilities and gene effects play a significant role in plant breeding programs [27]. General and specific combining ability effects give important genetic information in parent selection on the basses of their hybrids performance [28]. High GCA value including positive and negative indicate that the parental mean is superior or inferior to the general mean and gave information about the concentration of dominant gene with additive effects whereas SCA gives non-additive interactions. The selection of the parents was made on the combination of SCA, GCA and hybrid mean. The frequency of favorable genes increases with best combination was hybrid mean, favorable SCA and high GCA effects [29] and populations with high frequency of favorable alleles are good source for plant selection. Heterosis is the accumulation of dominant or partially dominant alleles help the Breeders to develop a product with hidden genetic potential which is expressed in the form of heterotic effects [30] and can be exploited for good yield production [31].

Both additive and non-additive gene effects play role in the control of anthesis-silking interval; whereas non-additive gene effects were observed for ear leaf area, number of kernel rows per ear, 100 grain weight, biological yield and vegetative dry matter [32] reported that prominent role of additive gene action in controlling number of kernel rows. However, 100 seed weight mainly affected by dominance effects. Additive and non-additive gene effects were reported by [32, 33]. It was evident that dominant gene has the most important effect on traits such as, kernel per rows, 100 kernel weights and kernel rows per ear controlled by additive genes.(Table 4)

In present study, positive highest and significant heterosis revealed by hybridDR-158 × Pak Afgoee and DR-198 × Pak Afgoee for 100 grain weight under water treatment 1 in season-I and II. Under water treatment 2 and 3, hybridsDR-158 × Pak Afgoee and DR-159 × Ev-1098 had positive significant heterosis for 100 grain weight in both seasons. The classification of corngermplasm in to heterotic group may help for exploitation of heterosis in corn [34].

## Conclusion

The present study showed that positive highest significant heterosis revealed by crosses DR-158 × Pak Afgoee andDR-198 × Pak Afgoee for 100 grain weight under water treatment1 in season-I and II and under water treatment 2 and 3 crossesDR-158 × Pak Afgoee andDR-159 × Ev-1098 had positive significant heterosis for 100 grain weight in season-I and II and theseare the hybrids with outstanding heterotic values.

## Authors' contributions

Conceived and designed the experiments: IR Noorka & JS (Pat) Heslop-Harrison, Performed the experiments: T Ullah, Analyzed the data: T Ullah & FS Awan, Contributed materials/ analysis/ tools: WN Mhiret, Wrote the paper: T Ullah & IR Noorka.

## Acknowledgement

The authors acknowledge the management of Corn and Millet Research Institute Sahiwal, Management of Fodder Research Institute, Sargodha and Plant Breeding and Genetic Department, University of Faisalabad, Pakistan, for providing the seed to conduct this research. The manuscript is a part of Ph. D, Dissertation of Mr. TaufiqUllah.



## References

1. FAO (2017). Statistical database. Food and Agricultural Organization of the United Nations. Rome, Italy.
2. Salasya BDS, Mwangi W, Verkuljl H, Odendo MA & Odenya JO (1998). An assessment of the adoption of seed and fertilizer package and role of credit in smallholder corn production in Kakamega and Vihiga districts, Kenya. Mexico, D. F.: CIMMYT and KARI.
3. Borlaug, NE & Dowswell, CR (2005). Feeding a world of ten billion people: A 21st century challenge. In proc. of "In the wake of double helix: From the green revolution to the gene revolution "27-31st May 2003 Bologna, Italy.
4. Cakir R (2004). Effect of water stress at different development stages on vegetative and reproductive growth of corn. *Field Crops Res* 89(1): 1-6.
5. Krivanek, AF, De Groote, H, Gunaratna, NS, Diallo, AO& Dennis (2007). Breeding and disseminating quality protein corn (QPM) for Africa. *African J of Biotechnol* 6(4): 312-324.

6. Sharief AE, El-Kalla SE, Gado HAE & Yousef A (2009). Heterosis in yellow corn. *Australian J of Crop Sci* 3: 146-154.
7. Sprague, GF& Tatum, LA (1942).General versus specific combining ability in single crosses of corn.*J of American Soc Agron* 34: 923-928.
8. Noorka IR, Khaliq I, Akram Z& Iqbal S (2009). Inheritance studies of physio-genetic traits in spring wheat under normal and moisture stress environments. *Inter J of Agri and Appl Sciences*. 1(1): 29-34.
9. Noorka IR & Tabasum S (2013). An empirical approach to get the vitality of a genotype to water stress tolerance in yield and yield contributing traits. *American J of Plant Sci* 4(5): 999-1003.
10. Amiruzzaman M, Islam MA, Hassan L & Rohman MM (2010). Combining ability and heterosis for yield and component characters in Corn. *Academic J of Plant Sci* 3(2): 79-84.
11. Kirda C, Topeu S, Kaman H, Ulger AC, Yazici A, Cetin M&Derici MR(2005). Grain yield response and Nitrogen fertilizer recovery of corn under deficit irrigation. *Photosynthetica*.19:312-319.
12. Steel RGD, Torrie JH & Dickey DA (1997). Principal and Procedures of Statistics. A biometrical Approach 3rd Ed. McGraw Hill Book Co. Inc New York 400-428.
13. Kempthorne O (1957). An Introduction to Genetic Statistics, John Wiley, New York, 458-471
14. Falconer DS&Mackay TFC (1996).Introduction to quantitative Genetics, 4th Edn. Longman Group Ltd.
15. WynneJC, Emery DA & Rice PW (1970). Combining ability estimates in *Arachis Hypogaea* L. II. Field performance of F1 hybrids. *Crop Sci* 10(6):713-715.
16. Sylvester BR, Scott RK & Wright CE (1990). Physiology in the production and improvement of cereals. HGCA, London, *Home-Grown Cereals Authority Res Rev* 18: 205-211.
17. Gregersen PL & Holm PB (2007).Transcriptome analysis of senescence in the flag leaf of wheat. *J of Plant Biotechnol* 5:192-206.
18. Stone PJ & Nicholas ME (1995) Comparison of sudden heat stress with gradual exposure to high temperature during grain filling in two wheat varieties differing in heat tolerance. I. Grain growth. *Australian J of Plant Physiol* 22: 935-944.
19. Blum A (2011). Plant breeding for water limited environment. Berlin: Springer.
20. Zarco PE, Gonzalez HVA, Lopez PM&Cristinay SMY (2005). Physiologcal markers for drought tolerance in maize (*Zea mays* L.). *Agrociencia* 39: 517-528.
21. Borrell AK, Hammer GL & Henzell RG (2000). Does maintaining green leaf area in sorghum improve yield under drought? II. Dry matter and yield. *Crop Sci* 40: 1037-1048.
22. Joshi VN, Pandiya NK & Dubey RB (1998). Heterosis and Combiningability for quality and yield in early maturing single cross hybrids of corn. *Indian J of Genetic and Plant Breeding* 58: 519-524.
23. Edmeades GO, Bolanos J, Hernandez M & Bello S (2003). Causes for silk delay in low land tropical corn population.*Crop Sci*33: 1029–1035.
24. Kiesselbach TA (1999).The structure and reproduction of corn. Cold Spring Harbor Laboratory Press, New York.
25. Welcker C, Boussuge B, Bencivenni C, Ribaut JM & Tardiu F (2007). Are source and sink strengths genetically linked in corn plants subjected to water deficit? A QTL study of the responses of

leaf growth and of anthesis-silking interval to water deficit. *J of Exper Bot* 58(2): 339-349.
26. Paul KK & Debnath SC (1999). Heterosis and combing ability for grain yield and its components in corn (*Zea mays* L.).*Bangladesh J of Agri* 24: 61-68.
27. Batool A, Noorka IR, Afzal M & Syed AH (2013). Estimation of heterosis, heterobeltiosis and potence ratio over environments among pre and post green revolution spring wheat. *J of Basic and Appl Sci* 9: 36-43.
28. Alamnie A, Naykar NY & Wali MC (2003). Combining Ability, heterosis and per se Performance of eight Characters in Corn. Karnataka, *J of Agri Sci* 16 (1): 131-133.
29. Marilla CF, ServioTC,Valter OR, ClibasV&Siu TM(2001). Combining ability for nodulation in common bean (*Phaseolus vulgaris* L.) genotypes from Andean and middle American gene pools. *Euphytica* 118: 265-270.
30. Weerasinghe OR, Perera ALT, deCosta WAJM, Jinadase DM & Vishnukanthasingham R (2004). Production of tomato hybrids for dry zone conditions of Srilinka using combining ability analysis, heterosis and DNA testing procedures. *Tropical Agri Res* 19: 79-90.
31. Stubler CW (1994). Heterosis in plant breeding. Plant Breeding Review, New York, pp 12: 227-251.
32. Konak C, Unay A, Serter E & Basal H (1999). Estimation of combining ability effects, hetrosis and heterobeltiosis by line × tester method in corn. *Turk J of Field Crops* 4: 1-9.
33. Lee Ho S & Shung LH (1995). Identification of heterotic patterns with inbred line testers in corn. *J of Agri Res China* 44: 242-250.
34. Bhatnager S, Betran FJ & Roomey LW (2004). Combining abilities of quality protein corn inbreds. *Crop Sci* 44: 1997-2005.