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GENETIC ANALYSIS AND COMBINING ABILITY STUDIES FOR MORPHO-PHENOLOGICAL AND GRAIN YIELD TRAITS IN SPRING MAIZE (*ZEA MAYS* L.)

Aamar Shehzad*[1], Muhammad Irfan Yousaf[1], Aamir Ghani[1], Khadim Hussain[1], Shahid Hussain[1], and Muhammad Arshad[1]

[1]*Maize and Millets Research Institute, Yusafwala, Sahiwal, Pakistan*
*Corresponding Author Email: aamarshehzad1763@gmail.com; 03339930811

ABSTRACT

Combining ability effects and gene action are imperative to assess utilization of genotypes based on their performances. In current study, a line × tester analysis comprising eight crosses developed by using four elite inbred lines and two testers was conducted to evaluate morpho-phenological and grain yield traits in spring maize during 2017-18 at Maize and Millets Research Institute, Yusafwala, Sahiwal. The purpose of this study was to evaluate the worth of lines, testers and hybrids using combing abilities (GCA and SCA) and mode of genetic inheritance. The genotypes were assessed in randomized complete block design (RCBD) with three replications. Analysis of variance revealed that mean square for genotypes was highly significant ($P<0.01$) for all twelve traits indicated the occurrence of significant variation among genotypes. The combining ability analysis for inbred lines (GCA), testers (GCA) and crosses (SCA) exhibited significant ($P<0.05$) or highly significant ($P<0.01$) results for most of the traits under study. Lines P-222, PLP-23 and DRF-25 proved good general combiners and crosses DRF-25 × Y-36, DRF-25 × Y-27 and P-222 × Y-27 proved good specific combiners for most of the studied traits. Ear (cob) length and yield exhibited additive genetic effects while all remaining traits depicted non-additive genetic effects. Selected inbred lines and crosses would prove a noble source for developing high yielding hybrids in future hybrid breeding program.

Key-words: Gene action, GCA, SCA, Line × tester analysis.

INTRODUCTION

Corn (2n = 20) is grown as a multipurpose crop in all over the world. It belongs to C4 plant type that fixes CO_2 efficiently to produce higher photo-assimilates (sink) which is utilized to produce grain yield (Bisen *et al*., 2018). It is estimated that corn will surpass globally to wheat and rice in production by 2020 due to greater area and yield increase (Gong *et al*., 2015). Maize kernels have diverse usages in human consumption, livestock feed, poultry feed and ethanol production (Beulah *et al*., 2018). It is primarily grown for feed poultry and livestock (65%), and human consumption (35%) (Yousaf *et al*., 2017). In Sub-Saharan Africa, approximately 208 million people are dependent mainly on maize as food and livelihood source (Yousaf *et al*., 2017).

Grain yield is the most vital and complex trait which is comprised of several other component traits i.e. number of kernel rows/cob, number of kernel / row and mean kernel weight (Borras and Vitantonio-Mazzini, 2017). Breeder need to develop and evaluate vast combinations of hybrids with key emphasis on improvement of yield components to get higher yield scores in diverse soil and climatic conditions (Bisen *et al*., 2018).

Agriculture is contributing 18.9% to economy of Pakistan and giving livelihood to 42.3% people. During 2017-18, maize was cultivated on 1,229 thousand hectares with 5.702 million tons production and 4,640 kg/ha yield. It is contributing 0.5% to GDP and 2.4% to value addition in agriculture (Economic Survey of Pakistan, 2017-18).

Population of Pakistan is growing at 2.4% and currently stood at 207 million that will reach at 302 million in 2050. This rapid upsurge demands increase in agricultural productivity to address food security issues and to feed massive population by developing superior high yielding corn hybrids (Economic Survey of Pakistan, 2017-18). Successful hybrid development program can efficiently be achieved by synthesizing and enhancement of germplasm with genetically diverse heterotic populations which enabled breeding program to breed superior cultivars (Beulah *et al*., 2018). Hybrid maize cultivars possessed superior yield potential to synthetics and composites. Currently, vast foreign currency is spent to import corn hybrid seeds due to less availability of locally breed hybrid seeds. To reduce these import expenses, there is need to develop high yielding F_1 hybrids along with other desired traits to fulfill local needs (Karim *et al*., 2018a).

Combining ability analysis provides details pertinent to desirable parents' qualities, magnitude and type of gene actions that control the polygenic characters. Line × tester analysis evaluates the combining abilities of crossed experimental materials i.e. general combining ability (GCA) and specific combining ability (SCA). Information related to both combining abilities is necessary to design next round of a breeding program (Shehzad *et al*., 2015b).

Many researchers used line × tester analysis to evaluate the genetic and combining ability effects of agro-morphological traits to generate high yielding hybrid cultivars (Shehzad *et al*., 2015a). The present study is conducted to assess the genetic values of lines, testers and hybrids for morpho-phenological and yield contributing traits in maize by using line × tester method.

MATERIALS AND METHODS

This experiment was conducted at Maize and Millets Research Institute, Yusafwala, Sahiwal (30.684611, 73.205293) during spring 2018. Sahiwal is located at 152 m elevation in central Punjab possessing semi-arid climatic conditions.

Plant material

The experimental material consisted of six inbred lines named P-222, PLP-23, DRF-25, SL-5, Y-36 and Y-27. These parental materials were obtained from germplasm collection of Maize and Millets Research Institute (MMRI), Yusafwala, Sahiwal.

Field Experiment

During the month of August-2017 (Kharif Season), four lines (P-222, PLP-23, DRF-25 and SL-5) and two testers (Y-36 and Y-27) were sown and crossed by following the line × tester design to obtain crossed seeds. Seeds of six parents and eight crosses were sown under randomized complete block design (RCBD) with three replications during Spring-2018. Each experiment unit consists of 4 × 0.76 m^2 dimension. The plant to plant (P×P) distance was 0.15 m and row to row (R×R) was 0.76 m. At three to four leaf stage, thinning was carried out to maintain recommended P×P distance. Optimum doses of NPK fertilizers 68:46:25 were applied for healthy growth. Plant protection measures were utilized to maintain the experimental crop healthy. At the maturity stage, ten plants of each genotype from each plot were randomly chosen to record data of F_1 plant for all the traits. All the plants in each experimental unit were considered for plot yield which is converted to kg/ha.

Data Collection

Data were recorded for twelve traits i.e. plant height (PH; cm), days to 50% anthesis (DA), days to 50% silking (DS), ear height (EHt; cm), ear weight (EWt; g), ear length (EL; cm), ear girth (EG; mm), kernels/ear (KE), 100 kernel weight (KWt; g), kernel length (KL; mm), kernel width (KWd; mm) and grain yield (kg/ha).

Statistical Data Analysis

Data were subjected to analysis of variance (Steel *et al*., 1997) to evaluate the significance of differences among F_1 hybrids and their parents. Line × tester analysis (Kempthorne, 1957) was used to estimate general combining ability (GCA) and specific combining ability effects (SCA). Statistical software package of TNAUSTAT (L × T analysis with parents) was practiced to assess ANOVA and combining abilities (https://sites.google.com/site/tnaustat/plant-breeding-heterosis) on October 10, 2018.

RESULTS

Analysis of Variance (ANOVA)

Highly significant differences were shown by genotypes and parents vs. crosses in all studied traits. Parents unveiled highly significant results for eleven traits except days to silking (3.3). Crosses showed highly significant differences for nine traits excluding ear (cob) length (2.8), kernel per ear (17421.3) and kernel weight (7.4). Lines displayed significant (KWt and KWd) or highly significant (PH, DS, EWt, EG, EHt, KL and yield) differences in nine traits. Testers depicted significant results in three traits (PH, DA, EL) and also highly significant results in other three traits (EWt, EG, yield). Nine traits (PH, DA, DS, EWt, EG, EHt, KL, KWd, yield) depicted highly significant differences for L x T. Finally, all the sources of variation revealed significant or highly significant results for plant height, ear weight, ear girth and yield traits (Table 1).

Genetic Effects, Mean and Range for Lines, Testers and Crosses

If GCA/SCA variance ratio is less than one, it indicates the presence of non-additive type of gene action i.e. dominance or over-dominance. It was observed that two traits (ear length and yield) exhibited additive genetic effects (-4.22 and 1.76) while all remaining depicted non-additive genetic effects (Table 2). Plant height unveiled 196.71 cm mean with 153-240 cm range values. Days to anthesis and days to silking exhibited 63.62 and 55.71

mean values with 58-72 and 59-73 range. Ear weight possessed 12.5-234 g range and 118.18 g mean. Ear length, ear girth and ear height exhibited mean values (14.38 cm, 38.28 mm, 67.07 cm) and range (7-20.8 cm, 24.6-48.3 mm, 28-109 cm), respectively. Mean and range for number of kernel per ear was 389.19 and range was 40-676. Kernel weight exhibited 30.86 g mean with 20-54 g range. Kernel length and width showed 9.68 mm and 8.07 mm mean with 5.2-12.9 mm and 5.5-10.08 mm range, respectively. Average of yield was 7299.79 kg/ha and range was 740-13793 kg/ha (Table 2).

General Combining Ability (GCA) effects for Lines and Testers

The GCA effects for plant height revealed DRF-25 has highly significant positive effect (12.04) and significant negative by SL-5 (-4.29) and P-222 (-4.13) (Table-3). None of line or tester turned out significant results for days to anthesis and ear length. For days to silking, line P-222 revealed highly negative GCA effect (-1.63) followed by DRF-25 (1.54). Three lines and both of the testers showed highly significant results for ear weight. Highest GCA results for ear weight were testified by SL-5 (-41.54) followed by DRF-25 (21.29). For ear girth, line SL-5 rendered highly negative significant effect (-4.83) proceeded by PLP-23 (2.19). The significant positive GCA effect for ear height was observed for lines DRF-25 (12.08) while negative significant effects showed by line P-222 (-7.75) and PLP-23 (-4.92). All the inbred lines and testers expressed highly significant effects for kernel per ear (Table-3). The highest effect for kernel per ear represented by line SL-5 (-95.50) proceeded by DRF-25 (53.67). Line SL-5 revealed significant GCA effects for kernel weight (-2.16), while line P-222 and SL-5 showed significant effects for kernel length (0.36, -0.76) and kernel width (0.44, -0.39) respectively. For yield, all the inbred lines and testers depicted highly significant GCA effects. The highest results were exhibited by line SL-5 (-3028.64) followed by P-222 (1616.45) and PLP-23 (782.86) for yield trait (Table 3).

Table 1. Mean square (ANOVA) of Line × Tester Analysis for Twelve Traits in *Zea mays* L.

SOV	**df**	**PH**	**DA**	**DS**	**EWt**	**EL**	**EG**	**EHt**	**KE**	**KWt**	**KL**	**KWd**	**Yield**
Replicates	2	3.0	0.4	0.6	18.34	2.2	1.8	10.5	0.6	1.4	0.1	0.1	4393.0
Genotypes	13	2231.7 **	55.1 **	62.3 **	18457.1 **	36.8 **	184.3 **	1281.1 **	147658.5 **	254.8 **	13.5 **	2.9 **	73692220.6 **
Parents	5	361.7 **	7.0 **	3.3	1322.7 **	11.7 **	26.3 **	251.7 **	26344.3 **	157.1 **	6.8 **	5.0 **	4697406.1 **
Crosses	7	332.2 **	6.6 **	10.3 **	3045.4 **	2.85	37.1 **	436.3 **	17421.3	7.4	1.8 **	0.9 **	12235852.4 **
Parents vs Crosses	1	24878.3 **	635.6 **	721.4 **	212011.0 **	401.0 **	2005.4 **	12341.3 **	1665890 **	2475.5 **	128.8 **	5.9 **	848860871.1 **
Lines	3	387.1 **	2.9	10 **	5013.6 **	3.2	64.4 **	461.1 **	25847.4	15.9*	1.6 **	0.7*	25588906.3 **
Testers	1	92.0 *	8.1 *	1	495.0 **	7.2 *	13.88 **	1.5	3082.6	0.8	0.6	0.2	2187688.1 **
L x T	3	357.4 **	9.83 **	13.8 **	1927.4 **	1.0	17.4 **	556.5 **	13774.7	1.2	2.4 **	1.4 **	2232186.7 **
Error	*26*	*4459.3*	*114.7*	*1.4*	*24.9*	*1.4*	*1.4*	*12.4*	*93.7*	*4.3*	*0.2*	*0.2*	*20602.2*

*: Significant at level of P<0.05, **: Highly significant at level of P<0.01, PH: Plant height (cm), DA: Days to 50% anthesis, DS: Days to 50% silking, EWt: Ear weight (g), EL: Ear length (cm), EG: Ear girth (mm), EHt: Ear height (cm), KE: Kernels/ear, KWt: 100 Kernel weight (g), KL: Kernel length (mm), KWd: Kernel width (mm), Yield (kg/ha).

Table 2. Genetic Effects, Range and Mean for Twelve Traits in *Zea mays* L.

Trait	**PH**	**DA**	**DS**	**EWt**	**EL**	**EG**	**EHt**	**KE**	**KWt**	**KL**	**KWd**	**Yield**
Effect	-0.12	-0.16	-0.22	0.15	-4.22	0.45	-0.20	0.02	-0.76	-0.19	-0.25	1.76
Range	153-240	58-72	59-73	12.5-234	7-20.8	24.6-48.3	28-109	40-676	20-54	5.2-12.9	5.5-10.08	740-13793.5
Mean	196.71	63.62	65.71	118.18	14.38	38.28	67.07	389.19	30.86	9.68	8.07	7299.79

PH: Plant height (cm), DA: Days to 50% anthesis, DS: Days to 50% silking, EWt: Ear weight (g), EL: Ear length (cm), EG: Ear girth (mm), EHt: Ear height (cm), KE: Kernels/ear, KWt: 100 Kernel weight (g), KL: Kernel length (mm), KWd: Kernel width (mm), Yield (kg/ha).

Table 3. General Combining Ability Effects for Twelve Traits in *Zea mays* L.

Inbred/ Trait	**PH**	**DA**	**DS**	**EWt**	**EL**	**EG**	**EHt**	**KE**	**KWt**	**KL**	**KWd**	**Yield**
P-222	-4.13*	-0.75	-1.63**	17.96**	0.82	0.76	-7.75**	16.00**	1.64	0.36*	0.44*	1616.45**
PLP-23	-3.63	-0.42	0.04	2.29	0.26	2.19**	-4.92**	25.83**	0.74	0.07	-0.06	782.86**
DRF-25	12.04**	0.42	1.54**	21.29**	-0.18	1.88**	12.08**	53.67**	-0.22	0.32	0.01	629.32**
SL-5	-4.29*	0.75	0.04	-41.54**	-0.91	-4.83**	0.58	-95.50**	-2.16*	-0.76**	-0.39*	-3028.64**
SE	*1.87*	*0.44*	*0.49*	*2.04*	*0.48*	*0.48*	*1.44*	*3.95*	*0.85*	*0.16*	*0.16*	*58.60*
Tester/ Trait	**PH**	**DA**	**DS**	**EWt**	**EL**	**EG**	**EHt**	**KE**	**KWt**	**KL**	**KWd**	**Yield**
Y-36	1.96	-0.58	-0.21	-4.54**	-0.55	0.76*	0.25	-11.33**	0.18	0.16	0.11	-301.92**
Y-27	-1.96	0.58	0.21	4.54**	0.55	-0.76*	-0.25	11.33**	-0.18	-0.17	-0.11	301.92**
SE	*1.32*	*0.31*	*0.34*	*1.44*	*0.34*	*0.34*	*1.02*	*2.80*	*0.60*	*0.11*	*0.12*	*41.43*

*: Significant at level of P<0.05, **: Highly significant at level of P<0.01, PH: Plant height (cm), DA: Days to 50% anthesis, DS: Days to 50% silking, EWt: Ear weight (g), EL: Ear length (cm), EG: Ear girth (mm), EHt: Ear height (cm), KE: Kernels/ear, KWt: 100 Kernel weight (g), KL: Kernel length (mm), KWd: Kernel width (mm), Yield (kg/ha).

Table 4. Specific Combining Ability Effects for Twelve Traits in *Zea mays* L.

Cross/ Trait	**PH**	**DA**	**DS**	**EWt**	**EL**	**EG**	**EHt**	**KE**	**KWt**	**KL**	**KWd**	**Yield**
P-222× Y-36	-4.63*	1.08	-0.29	-25.13**	-0.43	-1.36	-4.08	-13.00*	0.10	0.85**	0.42	-482.01**
PLP-23× Y-36	1.54	1.08	2.04**	11.21**	0.43	0.19	2.75	-16.17**	0.33	-0.70**	0.07	-468.07**
DRF-25× Y-36	10.21**	-1.42*	-1.62*	14.38**	0.27	2.34**	11.92**	69.50**	-0.67	-0.03	0.21	801.65**
SL-5× Y-36	-10.21**	1.42*	1.63*	-14.38**	-0.27	-2.34**	-11.92**	-69.50**	0.67	0.03	-0.21	-801.65**
P-222× Y-27	-1.54	-1.08	-2.04**	-11.21**	-0.43	-0.19	-2.75	16.17**	-0.33	0.70**	-0.07	468.07**
PLP-23× Y-27	7.12*	0.75	0.13	0.46	0.27	1.17	10.58**	40.33**	-0.23	0.12	0.71**	-148.43
DRF-25× Y-27	4.63	-1.08	0.29	25.13**	0.43	1.36	4.08	13.00*	-0.10	-0.84**	-0.42	482.01**
SL-5× Y-27	-7.13	-0.75	-0.12	-0.46	-0.27	-1.17	-10.58**	-40.33**	0.23	-0.12	-0.71**	148.43
SE	*2.65*	*0.31*	*0.69*	*2.89*	*0.68*	*0.68*	*2.03*	*5.59*	*1.2*	*0.23*	*0.23*	*82.87*

*: Significant at level of P<0.05, **: Highly significant at level of P<0.01, PH: Plant height (cm), DA: Days to 50% anthesis, DS: Days to 50% silking, EWt: Ear weight (g), EL: Ear length (cm), EG: Ear girth (mm), EHt: Ear height (cm), KE: Kernels/ear, KWt: 100 Kernel weight (g), KL: Kernel length (mm), KWd: Kernel width (mm), Yield (kg/ha).

Specific Combining Ability (SCA) Effects for Crosses

For studied traits, both positive and negative significant or highly significant SCA effects were observed among crosses (Table-4). For plant height, two crosses exhibited highly significant and four showed significant SCA effects. Crosses DRF-25 × Y-36 and SL-5 × Y-36 expressed highest SCA effects positively (10.21) and negatively (-10.21) respectively. Crosses (DRF-25 × Y-36 and SL-5 × Y-36) indicated significant effects (-1.42 and 1.42) for days to anthesis. Two crosses expressed highly significant (PLP-23 × Y-36 and P-222 × Y-27) and two (DRF-25 × Y-36 and SL-5 × Y-36) showed significant SCA effects for days to silking. For ear weight, six crosses depicted highly significant SCA effects in which highest effects were shown by P-222 × Y-36 (-25.13) and DRF-25 × Y-27 (25.13). None of the crosses showed significant or highly significant SCA effects for ear length and kernel weight. Two crosses (DRF-25 × Y-36 and SL-5 × Y-36) for ear girth (2.34, -.2.34), four crosses (DRF-25 × Y-36, SL-5 × Y-36, PLP-23 × Y-27 and SL-5 × Y-27) for ear height (11.92, -11.92, 10.58, -10.58), four crosses (P-222 × Y-36, PLP-23× Y-36, P-222 × Y-27 and DRF-25 × Y-27) for kernel length (0.85, -0.70, 0.70, -0.84), two crosses (PLP-23 × Y-

27 and SL-5 × Y-27) for kernel width (0.71, -0.71) showed highly significant SCA effects among eight crosses. Six crosses expressed highly significant and two showed significant specific combining ability effects for kernel per ear. Highly positive significant effects depicted by DRF-25 × Y-36 (69.50) followed by P-222 × Y-27 (40.33) for kernel per ear. For yield, six crosses indicated highly significant SCA effects in which highest positive effects were revealed by DRF-25 × Y-36 (801.65) followed by DRF-25 × Y-27 (482.01) (Table 4).

DISCUSSION

From the current study, it is apparent that significant variation among inbred lines and crosses were found for grain yield and yield contributing traits. The occurrence of significant genetic differences among the inbred lines suggests that substantial progress could be made for better grain yield selection and the development of high yielding maize hybrids. Similar studies were also intended by other scientists (Abdel-Moneam *et al*., 2009; Abrha *et al*., 2013; Dinesh *et al*., 2016; Shehzad *et al*., 2015c; Issa *et al*., 2018) who established significant differences among their genotypes.

GCA/SCA variances of different quantitative traits in maize were evaluated to calculate the influence of additive and non-additive (dominance or over-dominance) effects. GCA is utilized to calculate additive genetic behavior that differentiates genetic constituents of inbred genotypes and reveal its potential of utilization. SCA calculates the non-additive genetic behavior which is easily influenced by environmental variations and unable to inherit stably (Sun *et al*., 2018). Grain yield showed additive genetic effect for grain yield inheritance owing to high GCA/SCA variance ratio which is supported by Karim *et al*. (2018b) and contrary to Ali *et al*., (2018). Dinesh *et al*., (2016) studied that days to anthesis, days to silking, plant height, ear height and kernel yield exhibited non-additive genetic behavior in maize that partially supported the present study. Karim *et al*. (2018a) noted that days taken to silking showed non-additive genetic effect that support the current study while, days to anthesis, plant height, ear height and 1000 kernel weight possessed additive genetic behavior which is not in accordance to current study. Genotypic selection in early or later generation depends on genetic behavior of targeted traits. Shehzad *et al*. (2015b) recommended that selection in early generation should be attempted for those traits possessing additive genetic behavior. In contrary, selection should be postponed to later generation is beneficial for traits having non-additive genetic behavior.

Previous studies concluded that potential utilization of inbred lines would not be selected based on plant growth, but there is need to evaluate genotypes based on analysis of combining ability (Sun *et al*., 2018). Higher values of GCA and SCA genetic effects proposed that inbred lines and their crosses might be used to improve synthetic cultivars development and hybrids seed production, respectively (Malook *et al*., 2016). Significant positive and negative GCA and SCA effects were found in current study. For plant height, line DRF-25 proved good general combiner (12.04 cm) and DRF-25 × Y-36 verified good specific combiner (10.21cm) which suggested that lines possessing good GCA might be contributed to produce good specific combiners (crosses). Positive GCA and SCA effects for plant height suggested that positive correlation existed between plant height and grain yield under heat stress (Khodarahmpour, 2012; Dinesh *et al*., 2016). On the other side, Dinesh *et al*. (2016) also suggested that crosses with negative SCA effects could be used to develop lodging resistance hybrids. Selection of a cross with positive or negative combining ability effect depends upon whether the purpose of breeding is for tall stature, silage or lodging resistance. Similar good general and specific combiners for plant height were also evaluated by Abrha *et al*. (2013) (L1: 32.34, L19 × T1: 31.30); Dinesh *et al*., (2016) (L94: 27.68, L7 × L1: 12.91)) and Issa *et al*. (2018) (TZEI-124: 24.41, TZEI-17 × TZEI-13: 23.33).

For days to anthesis and silking, Dinesh *et al*. (2016) advised negative combining ability effects for breeding short duration hybrids and opposed positive effects because long growth period caused yield reduction under heat stress. Use of negative combining ability effects might be valuable in breeding early hybrids (Karim *et al*., 2018a). Cross DRF-25 × Y-36 for days to anthesis (-1.42) and P-222 × Y-27 for days to silking (-2.04) evinced as good specific combiners in the present study.

Bisen *et al*., (2018) assessed that ear girth and ear weight possessed positive and significant association with grain yield. Line DRF-25 selected as best general combiner (21.29 g) that contributed to best specific combiner DRF-25 × Y-27 (25.13 g) followed by DRF-25 × Y-36 (14.38 g) for ear weight. It advocated that good combing line might be beneficial for producing good hybrids.

SCA results for ear length and 100 kernel weight were non-significant. It might be due to lack of genetic variations among crosses for these traits depicted non-significant ANOVA results for crosses. Abdel-Moneam *et al*. (2009) unveiled that line P-4 (1.56) and cross P1×Y P2 (5.99) testified good combiners for 100 kernel weight.

Malook *et al*. (2016) suggested that selection of inbred lines and crosses for 100 kernel weight, ear length, ear girth, kernel rows per ear and kernel yield per plant would be beneficial for developing high yielding synthetic and hybrids. Line PLP-23 revealed highest positive GCA effect (2.19) while Cross DRF-25 × Y-36 exhibited highest positive SCA effect (2.34) and proved good combiners for ear girth. Malook *et al*. (2016) communicated the similar results for line W-64SP (0.51) and cross A-495 × A-239 (0.99) for ear girth.

For ear height, it seems that it possessed positive relation with plant height. Line DRF-25 expressed highest GCA effect for ear height as well as for plant height. Cross DRF-25 × Y-36 proved best specific combiner (11.92 cm) for ear height. Kernel per ear possessed positive effect on yield (Malook *et al*., 2016). Line DRF-25 (53.67) and cross DRF-25×Y-36 (69.50) unveiled as best general and specific combiners for kernel per ear, respectively.

Kernel length has positively effect on yield as it increased the shelling percentage. Only line P-222 revealed positive GCA effect (0.36) as well as P-222 × Y-36 expressed positive SCA effect (0.85) for kernel length and proved good combiners. Cross PLP-23 × Y-27 manifested good specific combiner (0.71) for kernel width.

For kernel yield, line P-222 rendered as good general combiner (1616.45) followed by PLP-23 (782.86) and DRF-25 (629.32). The performance of inbred line DRF-25 was excellent as it had ability to transfer his maximum performance in crosses i.e. cross DRF-25×Y-36 proved as good specific combiner (801.65) followed by DRF-25×Y-27 (482.01) for kernel yield. Chapman and Edmeades (1999) studied that kernel numbers are more important for getting higher yield than kernel weight. Bisen *et al*. (2018) calculated that grain yield possessed positive significant association with kernels/ear, kernels/row, shelling percentage, ears/plant, kernel rows/ear and seed index. Finally, a plant breeder always put his entire attention toward selection of maize plant possessing higher number of kernel rows/ear, kernels/row and kernels/ear for getting high yielding hybrids.

Conclusion

The outcome of current study revealed the presence of both types of gene actions i.e. additive and non-additive for controlling quantitative traits in maize. Significant result of ANOVA detected for all traits which disclosed the occurrence of genetic variation among genotypes. Three inbred lines (P-222, PLP-23 and DRF-25) were embarked as favorable for future breeding program based on better yield. Three crosses (DRF-25×Y-36, DRF-25×Y-27 and P-222×Y-27) showed highly significant positive tendency toward yield and would be used for developing high yielding hybrid and exploiting hybrid vigor. These genotypes will be further evaluated at wider agro-climatic conditions. Lastly, this study also unveiled that lines with good GCA have higher probability to deliver their performance in crosses.

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