The Pharma Innovation Journal 2021; 10(12): 2479-2482

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(12): 2479-2482

www.thepharmajournal.com
Received: 06-10-2021
Accepted: 20-11-2021

G Praveen Kumar
Department of Genetics and
Plant Breeding, College of
Agriculture, Rajendranagar,
Hyderabad, Telangana, India

N Sunil
Department of Entomology,
Winter Nursery Centre, ICAR-
Indian Institute of Maize
Research, Rajendranagar,
Hyderabad, Telangana, India

Farzana Jabeen
Department of Statistics and
Mathematics, College of
Agriculture, Rajendranagar,
Hyderabad, Telangana, India

JC Sekhar
Department of Entomology,
Winter Nursery Centre, ICAR-
Indian Institute of Maize
Research, Rajendranagar,
Hyderabad, Telangana, India

D Srinivasa Chary
Department of Statistics and
Mathematics, College of
Agriculture, Rajendranagar,
Hyderabad, Telangana, India

Corresponding Author:
G Praveen Kumar
Department of Genetics and
Plant Breeding, College of
Agriculture, Rajendranagar,
Hyderabad, Telangana, India

Gene action and combining ability studies for grain yield and its contributing characters in maize (*Zea mays* L.)

G Praveen Kumar, N Sunil, Farzana Jabeen, JC Sekhar and D Srinivasa Chary

Abstract

Evaluation of inbred lines for general combining ability (gca) provides useful information for the selection of parents in terms of performance of hybrids and elucidate the nature and magnitude of gene action involved in the expression of quantitative characters. In this context, 8 diverse maize inbred lines were crossed in diallel mating design to evaluate their gca for grain yield and its attributing traits. The analysis of variance revealed significant differences among the inbred lines for their per se performance as well as their gca. Similarly, the crosses differed significantly for per se performance and their specific combining ability (SCA) effects for all the traits under study. Significant effects of GCA and SCA indicating both additive and non additive gene effects were present in the material under study. Variance due to sca was larger than gca variance for all the characters indicating the preponderance of non additive gene action in the expression of various traits. Among the parents Bio-688 and BML-6 were found to be good general combiners for grain yield per plant and major yield attributing characters with significant and positive gca effects. The hybrids BML-6 × PFSR-46, BGS-337 × Bio-688 and BML-6 × Bio-688 showed high sca effects for grain yield and other important yield component characters.

Keywords: Maize, General combining ability, gene action, diallel

Introduction

Maize (*Zea mays* L.), belonging to the family Poaceae and tribe Maydeae, is one of the most important cereal crops and occupies a prominent position in global agriculture after wheat and rice. Among cereals, maize is rich in starch, proteins, oil and sucrose, due to which it has assumed significant industrial importance. Maize and its main by-products starch, syrup, glucose, gluten and oil are used in diversified industries like alcohol production, textile, paper, pharmaceuticals, cosmetic industry, edible oil industry, poultry feed and many chemical industries. Maize protein "Zien" has significant quantities of vitamin A, nicotinic acid, riboflavin, vitamin E and phosphorus. Maize oil obtained from germ of kernel is rich in polyunsaturated fatty acids and also contains high level of natural anti-oxidants, hence maize oil is ideal for heart patients.

The main goal of maize breeding is to obtain new hybrids with high genetic potential for yield and positive features that exceed the existing commercial hybrids. The commercial production of hybrids however, depends upon two factors *viz.*, the behavior of the line itself and the behavior of line in hybrid combination. The behavior of a line in hybrid combination is assessed through the estimation of general combining ability (*gca*) and specific combining ability (*sca*) effects. Combining ability of the inbred lines is the ultimate factor for determining future usefulness of the lines and helps in classifying inbred lines relative to their cross combinations.

Combining ability analysis is an important method to evaluate the prepotency of cultures to be used in breeding programme and to assess the gene action involved in various characters so as to design an appropriate and efficient breeding method. Combining ability analysis provides this information and is frequently used by plant breeders to choose parents with a high general combining ability and hybrids with high specific combining ability effects. Variance for GCA is associated with additive genetic effects, while that of SCA includes non-additive genetic effects, arising largely from dominance and epistatic deviations with respect to certain traits.

In a systematic breeding program, it is essential to identify superior parents for hybridization and crosses to expand the genetic variability for selection of superior genotypes.

The Diallel mating design as per Griffings method II and model 1 (1956) [1] is an appropriate method to identify superior parents and hybrids based on general combining ability and specific combing ability, respectively.

Materials and Methods

Eight diverse inbred lines of maize *viz.*, BGS-337, CM-139, BML-6, DML-1432, Bio-688, PFSR-46, Saf91×2#-7 and E-63 were crossed in diallel mating design without reciprocals during *Rabi*, 2018-19 at Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Rajendranagar, Hyderabad. Subsequently, during *Kharif*, 2019 the resulting 28 F_1 crosses along with three standard checks (DHM 117, NK 6240 and CMH-8-287) and parents were evaluated in randomized block desighn with three replications at Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad. Each entry was sown in two rows of four meters length with a spacing of 60 cm between rows and 20 cm between the plants. The data on twelve quantitative characters namely, plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of kernel rows per ear, number of kernels per row, 100 kernel weight, shelling percentage and grain yield per plant were recorded on five randomly selected competitive plants in each replication, whereas days to 50 per cent tasseling, days to 50 per cent silking, days to maturity were recorded on plot basis. Ear diameter without husk was measured in centimeters at the middle of the ear at the time of harvest with vernier calipers. Combining ability analysis was computed according to the model given by Diallel analysis as per Griffings method II and model 1 (1956).

Results and Discussion

Analysis for combining ability was carried out for yield and yield contributing characters and the mean sum of squares, are presented in Table 1.

The analysis of variance revealed that parents exhibited highly significant differences among themselves for all the traits studied indicating greater diversity in the parental lines. The crosses exhibited significant differences, indicating varying performance of cross-combinations. The parents vs. crosses which indicates average heterosis, was also significant for all traits, thus considerable amount of average heterosis was reflected in hybrids.

Variance due to GCA and SCA was found to be significant for all the traits at all locations indicating both additive and non additive gene actions were important in the inheritance of these triats.

A comparison of the magnitude of variance components due to *gca* and *sca* confirms the gene action in controlling the expression of traits. The ratio of GCA and SCA variance for all the traits under study *viz.*, days to 50 per cent tasseling (0.394), days to 50 per cent silking (0.442), days to maturity (0.497), plant height (0.043), ear height (0.132), ear length (0.050), ear diameter (0.075), number of kernel rows per ear (0.269), number of kernels per row (0.021), 100 kernel weight (0.210), shelling percentage (0.855) and grain yield per plant (0.034) was less than one which indicates that all these characters were predominantly governed by non-additive gene effects (Table 2). Similar findings were reported by Kanagarasu *et al.* (2010) [2] for grain yield per plant, cob diameter, cob length, plant height, ear height, 100 grain weight, grain rows per cob, days to 50 per cent tasseling and days to 50 per cent silking. Ali *et al.* (2012) [3] for number of grain rows per cob and 100-grain weight. Varaprasad and Shivani (2015) [4] for days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear height, ear length, ear diameter, number of kernels per row number of kernel rows per ear, 100 grain weight and grain yield per plant. Suthamathi and Nallathambi (2015) [5] for ear length, ear diameter, number of number of kernel rows per ear, number of kernels per row and grain yield per plant. Thakur (2016) [6] for days to 50 per cent tasseling, days to 50 per cent silking, days to maturity, ear diameter and 100 grain weight. Raihan *et al*. (2018) [7] for 100 grain weight, Patel *et al*. (2019) [8] and Sowjanya *et al*. (2019) [9] for yield and other contributing traits.

The general combining ability (*gca)* effects of eight parents and the specific combining ability (*sca*) effects of 28 hybrids for yield and yield contributing characters were estimated and were presented in Tables 3 and 4 respectively.

From the estimates of the *gca* effects it is clearly evident that none of the parents had good general combining ability for all the traits. The parents E-63 and CM-139 were early in flowering and maturity with significant and negative *gca* effects which were also had significant and negative *gca* effects for most of the other yield attributing traits *viz*., plant height (cm), ear height (cm), ear length (cm), 100 kernel weight and grain yield per plant while for ear diameter (cm), number of kernels per row and shelling percentage shown negative non significant *gca* effects suggesting that good combiners for earliness don't have good combining ability for grain yield and yield component traits. For the characters *viz*., ear length (0.793), ear diameter (0.094), number of kernels per row (2.059), 100-kernel weight (1.859), shelling percentage (0.874) and grain yield per plant (12.512) the parent Bio-688 was found to be good general combiner with significant and positive *gca* effects. The parent BML-6 was found to be good general combiner for plant height (6.335), ear height (8.373), ear diameter (0.301), number of kernel rows per ear (0.525), number of kernels per row (0.832) and grain yield per plant (9.132) with significant and positive *gca* effects where as the parent DML-1432 was good general combiner for plant height (9.908), ear height (4.993), ear length (0.603), 100-kernel weight (1.660) and grain yield per plant (4.608).

The parents which were good general combiner also good in per se porforamnce for most of traits, which indicates that predominant role of additive and additive x additive types of gene action. These results are comparable with findings of Suthamathi and Nallathambi (2016) [5] for ear length, ear diameter, number of number of kernel rows per ear, number of kernels per row and grain yield per plant, Thakur (2016) [6] for days to 50 per cent tasseling, days to 50 per cent silking, days to maturity, ear diameter and 100 grain weight, Raihan *et al*. (2018) [7] for 100 grain weight and Patel *et al*. (2019) [8] for yield and other contributing traits who reported the additive gene action.

Specific combining ability effects of crosses for grain yield and yield components revealed that none of the crosses had high-ranking sca effects for all the characters. The crosses BML-6 × E-63 and BGS-337 × E-63 had significant and negative *sca* effects for flowering and maturity traits. The cross combinations BML-6 × PFSR-46, BGS-337 × Bio-688, Bio-688 × PFSR-46, BGS-337 × Saf91×2#-7, and BML-6 × Bio-688 had significant and positive *sca* effects for most of the grain yield and yield components (Table 4.21). The hybrid BML-6 × PFSR-46 had high significant and positive *sca* effects for grain yield per plant (62.406), number of rows per plant (1.120), and ear diameter (0.601), BGS-337 × Bio-688 had high significant and desirable *sca* effects for Ear length (3.283), grain yield per plant (52.143) and ear diameter (3.28), Bio-688 × PFSR-46 for grain yield per plant (49.959) and number of kernels per row (6.641), BGS-337 × Saf91×2#-7 for grain yield per plant (38.463), Ear length (2.947), ear height (32.019), Plant height (19.167), number of kernels per row (5.193) and ear diameter, BML-6 × Bio-688 for grain yield per plant (35.566) and shelling percentage (2.563). The high *sca* crosses involved Bio-688 and BML-6 as one of the parent with good general combining ability either for grain yield and yield component traits. The similar results were observed by Olaw (2015) [10], Sumalini *et al.* (2015a) [11], Sumalini *et al.* (2015b) [12], Varaprasad and Shivani (2015) [4], Suthamathi and Nallathambi (2015) [5] and Patel *et al.* (2019) [8] who reported the non additive gene action for yield and other contributing traits. Considering the majority of crosses for all the characters investigated, high sca was either due to high x low or low x high or low x low combining parents which further substantiate the operation of non- additive gene action (additive x dominance and dominance x dominance type of epistatic interaction).

Table 1: Analysis of variance for combining ability for yield and yield component characters in maize

Source of variation	DF	Days to 5o% tasseling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Number of kernel rows per ear	Number of kernels per row	100-kernel weight (g)	Shelling percentage	Grain yield per plant (g)
Replicates	2	1.231	1.028	1.861	73.447	57.213	0.847	0.058**	0.254	5.894	0.887	1.312	242.621
Treatments	35	23.901**	26.617**	102.845**	3836.211**	1187.892**	18.508**	1.038**	3.455**	118.003**	87.609**	17.027 **	7329.825**
Parents	7	31.143**	39.714**	134.089**	1173.214**	886.809**	8.458**	0.437**	2.114**	12.098**	71.784**	43.559 **	658.553**
Hybrids	27	18.504**	20.707**	87.393**	579.772**	477.318**	3.135**	0.353**	2.145**	20.171**	43.774**	10.674 **	1404.872 **
Parent Vs. Hybrids	1	118.90**	94.50**	301.339**	110401.1**	22480.970**	503.938**	23.725**	48.214**	3500.807**	1381.925**	2.855	214002.500 **
Error	70	0.851	0.809	2.956	61.048	23.289	0.352	0.034	0.271	3..009	1.882	4.537	114.243
Total	107	8.397	9.255	35.61	1296.146	404.868	6.3	0.363	1.312	40.678	29.905	8.562	2476.880
GCA	7	19.337**	22.856**	93.190**	631.593**	489.686**	3.469**	0.275**	2.226**	10.387**	49.817**	15.693**	982.089**
SCA	28	5.124**	5.376**	19.555**	1440.523**	372.533**	6.845**	0.364**	0.883**	46.571**	24.049**	3.171**	2808.572**
Error	70	0.284	0.27	0.985	20.349	7.763**	0.117	0.011	0.090	1.003	0.627	1.512	38.081

* Significant at 5 per cent level; ** Significant at 1 per cent level

Table 2: Estimation of *gca* and *sca* variance for yield and yield component characters in maize

Source	Days to 5o% tasseling	Days to 50% Silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Number of kernel rows per ear	Number of kernels per row	100-kernel weight (g)	Shelling percentage	Grain yield per plant (g)
σ^2 *gca*	1.905	2.259	9.22	61.124	48.192	0.335	0.026	0.214	0.938	4.919	1.418	94.401
σ^2 *sca*	4.841	5.107	18.569	1420.174	364.77	6.727	0.352	0.793	45.568	23.422	1.659	2770.49
σ^2 *gca*/σ^2 *sca*	0.394	0.442	0.497	0.043	0.132	0.05	0.075	0.269	0.021	0.21	0.855	0.034

Table 3: Estimates of general combining ability (*gca*) effects of parents for yield and yield component characters in maize

Parnts	Days to 50% Tasseling	Days to 50% Silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100-kernel weight (g)	Shelling percentage	Grain yield per plant (g)
BGS-337	0.467*	0.408*	0.792*	8.428**	0.500	0.020	-0.073	-0.335**	-0.641*	2.646**	0.404	-0.145
CM-139	-1.233**	-1.292**	-3.308**	-6.525**	-11.987**	-0.420**	-0.069	**0.258****	-0.031	-1.538**	-0.549	-9.178**
BML-6	1.033**	1.642**	2.925**	6.335**	8.373**	0.133	0.301**	0.525**	0.832**	-0.928**	-1.229*	9.132**
DML-1432	-0.500*	-0.458*	-0.842*	9.908**	4.993**	0.603**	-0.086**	-0.342**	-0.573	1.66**	0.274	4.668*
Bio-688	1.000**	0.908**	2.458**	-7.078**	-5.460**	0.793**	0.094**	-0.462**	2.059**	1.859**	0.874*	12.512**
PFSR-46	0.567**	0.408*	0.392	-0.845	6.847	0.107	0.054	-0.395**	0.099	1.379**	-2.256**	-3.228
Saf91×2#-7	1.367**	1.308	2.992**	1.488	1.667*	-0.137	0.044	-0.035	-0.686*	-0.194	1.211**	3.992*
E-63	-2.70**	-2.925**	-5.408**	-11.712**	-4.933**	-1.100**	-0.266**	0.785**	-1.058**	-4.291**	1.271	-17.752**
CD (g_i) at P=0.05%	3.155	1.949	0.240	3.155	1.949	0.240	0.075	0.210	0.700*	0.554	0.860	4.316
CD (g_i) at P=0.01%	4.670	2.884	0.355	4.670	2.884	0.355	0.111	0.311	1.037**	0.820	1.273	6.388
CD (g_i-g_j) at P=0.05%	4.770	2.946	0.362	4.770	2.946	0.362	0.113	0.318	1.059**	0.838	1.301	6.526
CD (g_i-g_j) at P=0.01%	7.060	4.361	0.536	7.060	4.361	0.536	0.168	0.471	1.567**	1.240	1.925	9.658

Table 4: Estimates of specific combining ability (*sca*) effects for single crosses for yield and yield component characters in maize

Hybrids	Days to 50% Tasseling	Days to 50% Silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100-kernel weight (g)	Shelling percentage	Grain yield per plant (g)
BGS-337 × CM-139	1.063*	0.967*	0.100	10.165*	7.953**	0.196	0.198	0.260	2.538**	4.820**	1.320	22.266**
BGS-337 × BML-6	-0.87	-1.300*	-1.800	16.572**	9.393**	1.143**	0.295**	0.793**	4.408	2.277**	-1.967	17.389**
BGS-337 × DML-1432	-0.337	0.133	1.633	3.799	-15.493**	0.573	-0.485	1.127**	3.279**	-2.450**	0.33	11.619*
BGS-337 × Bio-688	-1.504**	-1.900**	-2.000*	19.119**	11.427**	3.283**	0.468**	0.047	3.248**	2.524**	0.963	52.143**
BGS-337 × PFSR-46	-0.737	-1.400**	-3.267**	14.419**	8.520**	-0.097	-0.059	-0.287	-2.326*	-2.930**	-2.007	-3.551
BGS-337 × Saf91×2#-7	0.796	0.7	1.133	32.019**	19.167**	2.947**	0.418**	0.687*	5.193**	3.777**	-0.173	38.463**

BGS-337 × E-63	-3.804**	-3.733**	-7.800**	36.952**	14.900**	2.443**	0.561	-0.067	4.831**	4.907**	-2.200	22.206**
CM-139 × BML-6	2.496**	3.400**	6.967**	18.059**	-3.187	0.550	0.025	-0.2	1.931*	3.027**	0.353	21.723**
CM-139 × DML-1432	-2.637**	-2.833**	-3.933**	11.085*	12.127**	0.646*	0.311**	-0.4	0.536	6.434**	-2.417*	19.953**
CM-139 × Bio-688	-1.470**	-1.533**	-3.233**	8.805*	9.7139**	0.756*	0.165	1.187**	4.304**	-0.760	1.717	13.543*
CM-139 × PFSR-46	-0.704	-0.367	-1.500	30.305**	11.073**	1.276**	0.205*	0.72	3.264**	2.087**	1.28	23.849**
CM-139 × Saf91×2#-7	1.830**	1.400**	4.233**	30.372**	13.853**	0.720*	0.148	0.093	2.783**	0.460	-1.32	10.129
CM-139 × E-63	-0.77	-1.033*	-2.367*	-6.495	-3.013	1.650**	0.225*	0.873**	4.654**	-0.210	-0.413	28.139**
BML-6 × DML-1432	1.096*	0.233	3.167**	18.625**	5.167	0.860*	0.675**	0	2.806**	2.024**	0.363	33.276**
BML-6 × Bio-688	-1.404**	-1.467**	-1.800	7.612	8.420**	0.436	0.261*	0.387	5.441**	4.364**	2.563*	35.566**
BML-6 × PFSR-46	-1.637**	-1.300*	-2.733**	13.912**	13.780**	1.290**	0.601**	1.120**	3.268**	4.177**	1.66	62.406**
BML-6 × Saf91×2#-7	-3.437**	-3.533**	-6.667**	13.512**	2.027	0.966**	0.078	-0.173	3.786**	-0.583	-1.44	15.886**
BML-6 × E-63	-4.704**	-4.300**	-7.933**	25.979**	12.827**	1.430**	0.755**	0.873**	-1.376	5.214**	0.667	19.529**
DML-1432 × Bio-688	-0.87	-1.033*	-3.367**	9.305*	1.800	2.133**	0.415**	0.187	2.646**	4.404**	1.46	25.863**
DML-1432 × PFSR-46	-0.104	0.467	-2.300*	11.472**	21.493**	-0.014	-0.045	-0.147	0.739	1.117	-1.21	-3.231
DML-1432 × Saf91×2#-7	0.096	0.567	-0.567	29.605**	12.473**	1.230**	0.465**	0.293	4.874**	3.190**	0.557	31.416**
DML-1432 × E-63	-1.837**	-2.200**	-3.833**	15.072**	2.140**	1.526**	0.141	0.940**	7.096**	-1.913*	0.93	20.159**
Bio-688 × PFSR-46	-0.604	-0.900	-1.933*	14.992**	2.080	0.896**	0.141	-0.027	6.641**	3.917**	1.39	49.959**
Bio-688 × Saf91×2#-7	-0.737	0.2	0.467	4.259	2.993	1.006**	0.218*	0.813**	2.493*	0.947	-2.943*	24.073**
Bio-688 × E-63	1.996**	2.767**	6.533**	25.192**	8.793**	1.003**	0.128	1.060**	-0.002	-3.273**	-1.003	6.083
PFSR-46 × Saf91×2#-7	-1.304*	-0.633	-0.133	16.025**	-18.913**	1.193**	0.025	-0.32	3.853**	1.40	2.820*	15.979**
PFSR-46 × E-63	2.096**	2.267**	3.600**	21.625**	11.353**	1.290**	0.368**	-0.073	2.691**	0.574	1.893	29.856**
Saf91×2#-7 × E-63	2.296**	2.367**	4.333**	26.159**	16.067**	1.000**	0.311**	0.233	1.609	4.414**	-0.74	21.536**
CD (s_{ij}) at P-0.05%	0.991	0.966	1.847	8.393	5.184	0.637	0.199	0.559	1.863	1.474	2.288	11.481
CD (s_{ij}) at P-0.01%	1.338	1.304	2.494	11.333	7.0	0.860	0.269	0.755	2.516	1.990	3.090	15.504
CD (s_{ij}-s_{ik}) at P-0.05%	1.466	1.429	2.733	12.418	7.670	0.943	0.295	0.828	2.757	2.180	3.385	16.988
CD (s_{ij}-s_{ik}) at P-0.01%	1.979	1.93	3.69	16.769	10.357	1.273	0.398	1.118	3.723	2.944	4.571	22.939
CD (s_{ij}-s_{kl}) at P-0.05%	1.382	1.348	2.576	11.708	7.231	0.889	0.278	0.78	2.599	2.0526	3.192	16.016
CD (s_{ij}-s_{kl}) at P-0.01%	1.866	1.82	3.479	15.81	9.765	1.200	0.375	1.054	3.510	2.776	4.31	21.627

* Significant at 5 per cent level; ** Significant at 1 per cent level

Conclusion

This study revealed that high general combining ability effects for yield and important yield contributing characters were noticed in the inbred lines BML-6 and Bio-688. These parents had resulted in the production of superior single crosses. Hence, these inbred lines can be considered as potential parents for future breeding programmes. The estimates of sca effects revealed that the cross combinations BML-6 × PFSR-46, BGS-337 × Bio-688, Bio-688 × PFSR-46, BGS-337 × Saf91×2#-7 and BML-6 × Bio-688 were observed most promising hybrids with high specific combining ability effects for grain yield and some of its attributes. These crosses may be tested under multi locations and can be developed as commercial hybrids or advanced for Selfing for the isolation of transgressive segregants or homozygous lines for use in breeding programmes.

Acknowledgement

The authors would like to thanks the Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Rajendranagar and Professor Jayashankar Telangana State Agricultural University for providing funds and facilities for the carrying out research work.

References

1. Griffing O. Concept of general and specific combining ability in relation to diallel crossing system. Australian Journal of Biological Sciences. 1956;9:463-493.
2. Kanagarasu S, Nallathambi G, Ganesan KN. Combining ability analysis for yield and its component traits in maize (*Zea mays* L.). Electronic Journal of Plant Breeding. 2010;1(4):915-920.
3. Ali G, Ahmed I, Dar SA, Iqbal AM. Combining ability analysis for yield and its component traits in high altitude maize (*Zea mays* L.) Inbreds. Advances in life Science's. 2012;1(1):66-69.
4. Varaprasad B, Shivani D. Studies on combining ability for yield and yield components in maize (*Zea mays* L.). Forage Research 2015;41(3):147-151.
5. Suthamathi P, Nallathambi G. Combining Ability for Yield and Yield Attributing Traits Under Moisture Stress Environments in Maize (*Zea mays* L.). Electronic Journal of Plant Breeding. 2015;6(4): 918-927.
6. Thakur S. Genetic analysis of yield and its components in maize (*Zea mays* L.) using line × tester analysis, 2016. http://krishikosh.egranth.ac.in/handle/1/91094
7. Raihan HZ, Sultana S, Hoque M. Combining Ability Analysis for Yield and Yield Contributing Traits in Maize (*Zea mays* L.). Bangladesh Journal of Agricultural Research. 2019;44(2):253-259.
8. Patel K, Gami RA, Kugashiya KG, Chauhan RM, Patel RN, Patel RM. Gene Action and Combining Ability Analysis for Kernel Yield and its Attributing Traits in Maize (*Zea mays* L.). Electronic Journal of Plant Breeding. 2019;10(2):370-376.
9. Sowjanya PR, Gangappa E, Ramesh S. Combining Ability for Grain Yield and its Component Traits in Maize (*Zea mays* L.). Journal of Experimental Biology and Agricultural Sciences. 2019;7(4):376-381.
10. Owusu GA, Nyadanu D, Obeng-Antwi K, Amoah RA, Danso FC, Amissah S. Estimating gene action, combining ability and heterosis for grain yield and agronomic traits in extra-early maturing yellow maize single-crosses under three agro-ecologies of Ghana. Euphytica. 2017;213:287.
11. Sumalini K, Pradeep T, Manjulatha G. Effect of moisture stress on combining ability and gene action for polygenic traits in maize. Maydica. 2015;60 (1):1-4.
12. Sumalini K, Pradeep T, Sravani D, Rajanikanth E. Gene action and heterosis for yield and yield traits in maize (*Zea mays* L.). Maize Journal. 2015;4(1&2):1- 6.