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Evaluation of diallel crosses of maize at multilocation (*Zea mays* L.) for saline tolerance

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A diallel cross was produced using diverse maize (*Zea mays* L.) germplasm of saline tolerant and saline susceptible maize lines as parents. Agronomic performance of the offspring of the diallel cross was examined. Eight germplasm lines bearing diversified agronomic traits of five known tolerant and susceptible lines were involved as parents of the diallel cross that was evaluated at three different ecological areas viz. Gazipur, Benerpota, and Kaliganj. CZ-29 and CZ-26 had positive and significant general combining ability (GCA) effects for yield in both the saline environments, where CZ-12 possessed negative and significant GCA effects for yield in the same areas but none of the parents exhibited either significantly positive or negative GCA in Gazipur location. Of the saline tolerant lines evaluated, CZ-29 was a good source for increased yield with significant and positive GCA values in both the saline environments that was also responsible for dwarfness and earliness in all locations. CZ-26×CZ-24 yielded well except at Benerpota with an additional benefit of shorter plant type across all environments. Hybrid CZ-29×BIL-65, however, was consistent and promising over the environments for bold seed and higher yield that ranked 2nd at Benerpota (4.81 t ha^{-1}) and Kaliganj (6.73 t ha^{-1}) and 3rd at Gazipur (7.40 t ha^{-1}) location for yield having significant positive specific combining ability (SCA) effects at Gazipur and Kaliganj. Moreover, six hybrids either significantly or not consistently decreased yield over the locations with negative SCA. However, considering the overall performance of the hybrids, the involvement of saline susceptible or tolerant parents was not consistent in the present study. Crosses between saline tolerant lines did not produce any tolerant hybrids or dwarf parents did not produce dwarf hybrids except CZ-29×CZ-36 that was able to produce shorter hybrid for all the locations. Therefore, among the lines evaluated in this diallel cross having a distinct different genetic background, CZ-28 and CZ-29 contributed to earliness; CZ-29 and BIL-65 reduced plant height; CZ-12 increased seed size; CZ-26 and CZ-29 improved yield. Thus, these lines should be useful sources of alleles for pyramiding, earlier maturity, shorter plant heights, increased seed size and improved yield into desired breeding lines.

Key words: Diallel, maize, saline, environments, general combining ability, specific combining ability.

INTRODUCTION

Maize is a high yielding cereal crop and has key importance in assuring the world food security (Rohman et al., 2019). In Bangladesh, maize crop has been recognized as one of the most important for the expansion of its agricultural production. Recently, maize has been cultivated around the year in different agroecological zones of Bangladesh. Besides the expansion of the maize crop in time, it also has occurred extensively in space by opening new frontiers, thus increasing the variation of environments (latitude, altitude, fertility, biotic and non-biotic stresses, etc.). Such great changes justify the interest for new sources of germplasm to increase the chances of success of breeding programs to attend the new and expanding demands for adapted and outstanding genotypes. Recently, there has been an increasing interest for new sources of germplasm, particularly focusing the resistance or tolerance to several kinds of stresses (Basso and Miranda, 2001; Oliveira et al., 2015) like soil salinity.

Salinity is one of the major environmental constraints that severely limit crop production and productivity in many parts of Bangladesh (Rohman et al., 2019). In modern times, nearly 20% of arable land and 50% of irrigated land in the world are suffering from salt stress, which causes a great threat to agricultural production and surprisingly this area is still increasing (Yamaguchi and Blumwald, 2005; Rohman et al., 2019). In Bangladesh, more than 30% of the net cultivable land is in the coastal area. Of the 2.85 million ha of coastal and off-shore areas, about 1.0 million ha of arable land are affected by varying degrees of soil salinity (Karim et al., 1990). It is being speculated that the frequency and intensity of salinity would intensify in the years ahead in response to climate change. There are many evidences which show that abiotic stresses such as salinity limit agricultural production throughout the world (Wani and Gosal, 2011; Hussain Wani et al., 2013; Yadav et al., 2014). Therefore, one of the possible ways to ensure future food needs of an increasing world population involves the development of crop varieties which are more tolerant to salt for efficient utilization of problemtic soil like salinity. However, the progress in developing salt stress tolerant crops is significantly hampered by the physiological and genetic complexity of this trait (Wu et al., 2013). Being a C_4 plant, maize has the good photosynthetic ability. It could be cultivated from coastal areas to high latitude because of the high level of adaptability. Maize is a highly polymorphic crop carrying a high level of genetic variability. Grain yield and yield contributing components are complex traits and are the results of genetic and environmental effects and their interactions (Aslam et al., 2006; Iqbal et al., 2012; Aslam et al., 2015; Maqbool et al., 2015). Hence, understanding of abiotic stress tolerance mechanisms is imperative for crop improvement in stress tolerance.

Breeders perceived the need to broaden the maize germplasm base ensuring continued genetic gain and avert risks associated with a narrow germplasm base (Eberhart, 1971; Darrah and Zuber, 1986; Holley and Goodman, 1988; Mungoma and Pollak, 1988). Much work has been done evaluating the introgression of exotic germplasm into commonly used, elite inbreds from maize improvement programs around the world. However, the exploitation of useful alleles from exotic germplasm is difficult because such materials are often unadopted and agronomically deficient (Crossa et al., 1987; Castillo-Gonzalez and Goodman, 1989). Inbred lines are used for hybrid development and their worth is considered by their performance in combination with different other inbred lines. The ability of a line to transfer its performance to others is described as combining ability of inbred line. Combining ability of inbred lines gives information about the genetic nature of quantitative traits and also conducive for selection of most appropriate parents to be used for heterosis breeding. The breeding value of accession based on mean performance is regarded as general combining ability (GCA) which is an indicator for the extent of additive gene action. The predominance of GCA is conducive for the improvement of selection efficiency in segregating populations (Bocanski et al., 2009). Specific combining ability (SCA) is the cumulative performance of any two accession since their specific hybrid combination that shows the extent of non-additive gene action. Dominance and additive gene actions are effectively used for the improvement of hybrids (Kumar et al., 2012). The additive genes have been shown to be more important than dominant genes for higher grain production for maize (Aliu et al., 2010).

Diallel crosses method is an effective mating design (Gardner and Eberhart, 1966) that has been extensively used to attain information of parental lines and their hybrid crosses in different crops on the GCA and the SCA (Xiang and Li, 2001). However, Diallel mating design is most appropriate for the assessment of the potential of inbred lines, because they are crossed in all possible combinations (Yan and Kang, 2003). Germplasm lines from Africa (Ojo et al., 2007), subtropical origin (Beck et al., 1991), semi-exotic origin (Eberhart, 1971), Iran (Zare et al., 2011), China (Glover et al., 2005), and lowland tropical origin have all been evaluated via diallel crosses scheme to determine combining ability for yield and heterotic patterns. Diallel cross in maize over locations has been reported for aflatoxin (Henry et al., 2014) and for high land yield (Kayaga et al., 2017). However, diallel schemes in maize over locations for salt tolerance have not yet been reported. Therefore, the purpose of this study was to study the degree of adaptability of different maize hybrids under varied saline environments based on inheritance and the combining ability of parents and hybrids for the development of well-adapted maize hybrids for saline

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Table 1. Pedigrees, racial origin, and phenotypic characteristics of lines used in a diallel cross.

S/N	Parental code	Collected from	Characteristics
1	CZ-28	BARI	Tall and saline susceptible
2	CZ-29	BARI	Short and medium saline tolerant
3	BIL-65	BARI	Medium Tall, bold grain and medium saline tolerant
4	CZ-36	BARI	Short and saline tolerant
5	CZ-12	BARI	Short and saline tolerant
6	CZ-26	BARI	Tall and saline susceptible
7	CZ-24	BARI	Tall and saline tolerant
8	9MG	BARI	Tall and moderate saline tolerant

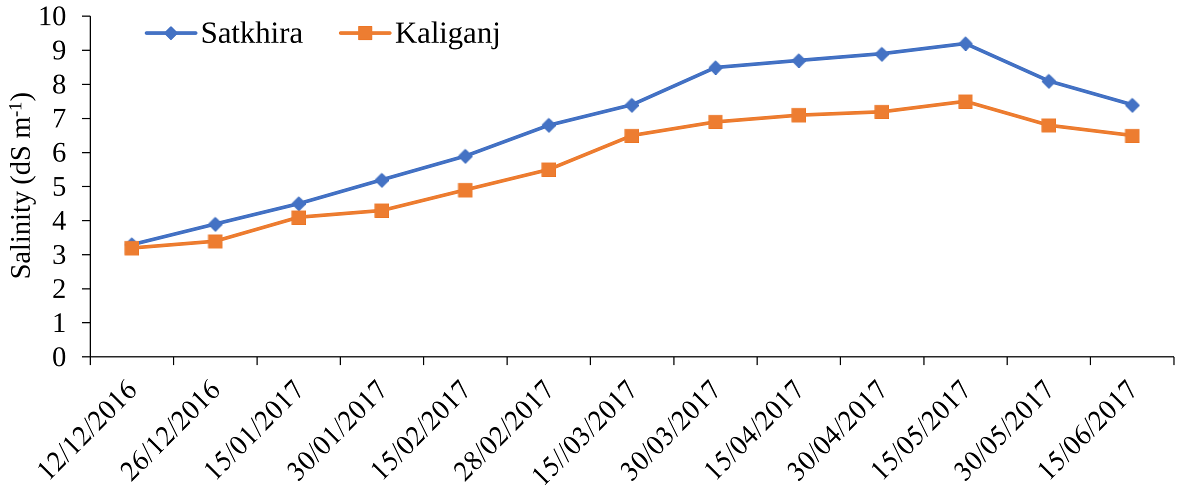

Figure 1. Soil salinity level in maize field at Satkhira and Kaliganj.

environment.

MATERIALS AND METHODS

Plant materials

Eight different salt tolerant and sensitive maize inbred lines (Table 1) collected from Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI) were used in this study. The inbreds were crossed in a half diallel fashion without the reciprocals during winter in 2015-2016 at BARI, Gazipur, Bangladesh. The subsequent 28 F1's and their 8 parents were evaluated in a randomized complete block design (RCBD) with three replications in three locations: 1. Gazipur (as non-saline area, 2. Benerpota, Satkhira (as comparatively high saline area) and 3. Kaliganj, Sathkira (as medium saline area) in the subsequent (winter) season of 2016-2017. The soil salinity levels of two locations were monitored with digital EC meter (Hanna 993310). The salinity level of Benarpota ranged 3.3 to 9.2 dSm^{-1} while the level of Kaliganj ranged 3.2-7.5 $dS\ m^{-1}$ (Figure 1).

Experiment settings, crop management, and data recording

Seeds of each entry were sown in two rows of 4 m plot on 15 December, 2016 at Gazipur and 20 December, 2016 at Satkhira and Kaliganj. The spacing between rows was 60 cm and plant to plant distance was 25 cm. Fertilizers were applied at 250, 55, 110, 40, 5 and 1.5 kg ha^{-1} of N, P, K, S, Zn, and B, respectively, according to recommened dose (Amiruzzaman et al., 2011). First irrigation was applied on 20th days after seed sowing while 2nd irrigation before flowering. One plant per hill was maintained after proper thinning. Agronomic and yield related traits of the plants were recorded on five randomly selected competitive plants. Agronomic trait includes days to tasseling, days to silking, anthesis silking interval (days), plant height (cm) and ear height (cm). In each plot, when 50% plants produced male flower, it was recorded as days to tasseling. Similarly, for days to silking, 50% silking of the plot was recorded. For the trait anthesis silking interval (ASI), days between 50% anthesis and 50% silking was considered. For plant height, ear height as well as yield related recorded traits like number of grains/plants, 100-grain weight (g) and grain yield (g) were measured from randomly selected 10 plants for each replication, and converted to ton ha^{-1}. Cobs were harvested at physiological maturity.

Statistical analysis

Data were analyzed using Statistical analysis software Plant Breeding Tools (Version 1.4) following the diallel mating design of Griffing Method IV in multi environments (Griffing, 1956).

Table 2a. ANOVA of diallel analysis for days to tasseling, days to silking, anthesis silking interval, plant height, 100-grain weight and yield of maize evaluated at three different locations.

Source	df	Mean squares					
		DT	DS	ASI	PH (cm)	100-GW (g)	Yield (t ha^{-1})
Crosses	27	33.12**	25.27	10.24	868.49**	95.73**	4.32**
Crosses×Env.	54	13.34**	15.09**	12.99**	380.99**	14.22**	1.73**
GCA	7	85.30**	67.34	20.73	2134.24	81.44**	3.15*
SCA	20	14.86	10.54	6.57	425.48*	100.74**	4.73*
GCA × Env.	14	14.9**	28.49**	16.77**	870.89**	19.41**	0.74
SCA × Env.	40	12.79**	10.40**	11.66**	209.52**	12.40**	2.08**
Residual	162	2.09	3.0	3.29	81.06	5.50	0.518

*Significant at $P < 0.05$,** Significant at $P < 0.01$. GCA: general combining ability; SCA, specific combining ability; DT, days to tasseling; DS, days to silking; ASI, anthesis silking interval; PH, plant height; 100-GW, 100-grain weight.

Table 2b. Location wise diallel analysis of variance for days to tasseling, days to silking, anthesis silking interval, plant height, 100-grain weight and yield of maize grown at Gazipur, Benerpota and Kaliganj.

Source	df	Mean squares					
		DT	DS	ASI	PH (cm)	100-GW (g)	Yield (t ha^{-1})
Gazipur							
Crosses	27	21.01**	32.11**	9.36**	412.85**	34.13**	4.39**
GCA	7	14.35*	32.11**	7.61**	404.08**	21.49*	0.385
SCA	20	4.43**	3.21*	1.55	44.35	7.84**	1.84**
Error	54	1.22	1.44	1.13	25.78	3.39	0.324
Benerpota							
Crosses	27	32.01**	13.23**	23.04**	961.22**	45.52**	0.72**
GCA	7	21.09*	6.24	8.41	832.18**	8.16	0.359
SCA	20	7.02**	3.77**	7.42**	141.28**	17.63**	0.197**
Error	54	0.84	0.59	1.26	38.39	1.68	0.049
Kaliganj							
Crosses	27	6.77**	10.10**	7.03**	256.41**	44.52**	2.69**
GCA	7	2.92	3.09	2.35	55.73	10.44	0.799
SCA	20	2.02**	3.46**	2.33**	95.87**	16.38**	0.93**
Error	54	0.03	0.97	1.00	16.89	0.44	0.149

*Significant at $P < 0.05$. ** Significant at $P < 0.01$. GCA, general combining ability; SCA, specific combining ability; DT, days to tasseling; DS, days to silking; ASI, anthesis silking interval; PH, plant height; 100-GW, 100-grain weight.

RESULTS AND DISCUSSION

The significance of GCA, SCA, and environmental effects were calculated where the interactions with the environment were highly significant for all characters (Table 2a). Since the interactions were significant, a genetic analysis was performed separately for each of the three environments (Table 2b). None of the traits combined showed significant GCA and SCA for all the three environments. Where the SCA had highly significant sources of variation for all the characters across, the environments with the exception being the Gazipur location at which SCA for anthesis silking interval and plant height were not significant. In the case of GCA, the trait yield demonstrated non-significant variation in all the environments where, the site Kaliganj indulged GCA to exhibit non-significant source of variation for all the traits, although Naidoo et al. (2002) and Williams et al. (2008) reported that significance of GCA and SCA for agronomic traits of interest is common. However, the variances due to GCA were much higher in magnitude than SCA for all the characters except 100 grain weight and yield indicating the prevalence of additive gene effects for the inheritance of these traits.

Table 3. Estimated general combining ability effects on days to tasseling, days to silking, anthesis silking interval, plant height, 100-grain weight and yield for 8 parental lines of a diallel cross of maize grown at Gazipur, Benerpota and Kaliganj.

Inbred	Days to tasseling			Days to silking			Anthesis silking interval		
	Gazipur	Benerpota	Kaliganj	Gazipur	Benerpota	Kaliganj	Gazipur	Benerpota	Kaliganj
CZ-28	-0.875*	-0.708*	-0.035	-3.264**	-0.750*	-0.875*	-2.389**	-0.042	-1.007**
CZ-29	-0.819	-1.597**	-0.479**	0.181	-0.472	-0.319	1.000*	1.125*	0.132
BIL-65	-0.875*	-1.097**	0.299**	-1.264**	-0.861**	0.125	-0.389	0.236	-0.396**
CZ-36	0.903*	0.681	-0.118	0.847	0.861**	0.319	-0.056	0.181	0.854**
CZ-12	-2.097**	-1.597**	0.410**	-2.153**	-1.417**	1.292**	-0.056	0.181	0.715**
CZ-26	2.292**	3.069**	0.965**	3.514**	0.861**	0.375	1.222**	-2.208**	-0.035
CZ-24	1.958**	2.514**	0.326**	2.681**	1.472**	-0.014	0.722	-1.042*	-0.507**
9MG	-0.486	-1.264**	-1.368**	-0.542	0.306	-0.903*	-0.056	1.569**	0.243

*Significant at $P < 0.05$. **Significant at $P < 0.01$.

Table 3. Contd

Inbred	Plant height (cm)			100-grain weight (g)			Yield (t ha^{-1})		
	Gazipur	Benerpota	Kaliganj	Gazipur	Benerpota	Kaliganj	Gazipur	Benerpota	Kaliganj
CZ-28	-2.86	-5.53*	0.325	0.347	-0.708	-0.875**	0.012	-0.384**	-0.050
CZ-29	-12.72**	-13.24**	-0.64	2.79**	-0.097	-0.097	0.041	0.366**	0.379*
BIL-65	-10.25**	-15.34**	3.93*	-1.153	-0.708	-0.875**	0.056	-0.043	-0.052
CZ-36	2.51	12.37**	-4.16*	-1.264	0.347	-0.319	-0.060	0.236**	0.069
CZ-12	3.07	-6.30*	1.24	0.958	1.79**	3.014**	-0.253	-0.191*	-0.480**
CZ-26	10.40**	13.96**	-0.803	-0.875	0.681	0.347	0.184	0.174*	0.322*
CZ-24	8.37**	11.66**	3.91*	-2.88**	-2.04**	-1.15**	0.424	-0.103	0.369*
9MG	1.50	2.43	-3.79*	2.07**	0.736	-0.042	-0.404	-0.054	-0.556**

*Significant at $P < 0.05$. **Significant at $P < 0.01$.

Malik et al. (2004) in their study also found higher GCA variances than SCA for days to pollen shedding, plant height, and ear height. Besides this, both GCA and SCA effects showed significant interaction with environments for all the traits with the only anomaly being yield for GCA (Table 2b). Nass et al. (2000) reported that both GCA and SCA can interact with environments which revealed the need of selecting different parental lines for hybrids for different ecological situations.

Days to tasseling

Consistent GCA effects for days to tasseling were observed where 7 of the 8 lines evaluated were significant in at least two environments. The lines CZ-28, CZ-29 and 9MG contributed to earliness in all the three environments (Table 3). Conversely, the GCA effects for CZ-26 and CZ-24 were highly significant and positive and that led to late tasseling across the three environments.

The two saline tolerant lines BIL-65 and CZ-12

Table 4. Mean days to tasseling (DT) for hybrids with significant specific combining ability (SCA) effects in at least one of the three environments: Gazipur, Benerpota, Kaliganj.

Parental combination	Gazipur		Benerpota		Kaliganj	
	DT	SCA effect	DT	SCA effect	DT	SCA effect
CZ-28×CZ-29	82	3.47**	76	1.32**	74	-0.23
CZ-28×BIL-65	77	-1.14	74	-1.52**	73	-2.01**
CZ-28 × CZ-36	82	1.41	78	1.04**	74	-0.59**
CZ-28×CZ-12	77	-0.59	73	-1.35**	77	1.88**
CZ-28×CZ-26	83	1.69	76	-3.02**	77	1.33**
CZ-28×CZ-24	79	-1.98*	83	4.54**	74	-1.04**
CZ-28×9MG	76	-2.87**	74	-1.02**	74	0.66**
CZ-29×BIL-65	76	-2.53**	74	-0.63	74	-0.56**
CZ-29×CZ-36	80	0.02	75	-0.74*	74	-0.15
CZ-29×CZ-12	74	-2.98**	72	-1.79**	77	1.99**
CZ-29×CZ-26	83	0.97	79	0.54	74	-1.23**
CZ-29×CZ-24	83	1.30	80	2.10**	74	-0.92**
CZ-29×9MG	79	-0.25	73	-0.79*	74	1.10**
BIL-65×CZ-36	81	1.08	79	2.10**	74	-0.92**
BIL-65×CZ-12	81	3.75**	75	0.37	77	1.55**
BIL-65×CZ-26	81	-0.64	79	-0.29	77	0.99**
BIL-65×CZ-24	82	1.02	81	2.60**	77	1.63**
BIL-65×9MG	77	-1.53	72	-2.63**	73	-0.67**
CZ-36×CZ-12	79	-0.37	76	-0.07	74	-1.04**
CZ-36×CZ-26	83	-0.75	83	2.26**	77	1.41**
CZ-36×CZ-24	81	-2.09*	74	-6.52**	76	0.55**
CZ-36×9MG	81	0.69	78	1.93**	74	0.74**
CZ-12×CZ-26	79	-1.42	81	2.87**	74	-2.12**
CZ-12×CZ-24	82	1.58	78	-0.24	74	-1.48**
CZ-12×9MG	78	0.02	74	0.21	73	-0.79**
CZ-26×CZ-24	83	-1.81	79	-3.57**	77	0.96**
CZ-26×9MG	84	1.97*	80	1.21**	73	-1.34**
CZ-24×9MG	84	1.97*	79	1.10**	74	0.30

*Significant at $P < 0.05$. ** Significant at $P < 0.01$.

flowered lately in Kaliganj environment (Table 3).

Hybrids male flowering for the three environments averaged 80, 77, and 25 for tasseling for Gazipur, Benerpota and Kaliganj, respectively (Table 4). The SCA effects for tasseling varied but none of the hybrids were positive and significant across the environment where only seven hybrids in two of three environments performed similarly (Table 4). Among the seven late maturing hybrids, only three included saline susceptible line as a parent.

Again, seven hybrids had negative and significant SCA effects for days to tasseling at two of the three environments. Of these seven hybrids, three of them contained only one saline susceptible line (CZ-28) in the pedigree (Table 4). The parent BIL-65 leads three hybrids to negative tasseling days in all the environments where negative and significant SCA in at least two of the three environments. The two pedigrees (CZ-28×BIL-65 and BIL-65×9MG) represent the extremes of maturity in both saline areas with respect to SCA effects and would be a highly desirable breeding objective. Although such results are not available so far in saline condition, Amiruzzaman et al. (2011) reported similar results in normal soil condition.

Days to silking

The GCA effects fluctuated for days to silking where only 2 inbreds (CZ-28 and CZ-12) of the 8 evaluated showed significance across the three environments where the saline susceptible line CZ-28 was negative in all sites and responsible for earliness (Table 3). Conversely, the GCA effects for another saline susceptible line CZ-26 were positive in all environments and highly significant other than Kaliganj area that led to late silk emergence across the environments. The line CZ-29 was non-significant across the environments but contributed to earliness in

Table 5. Mean days to silking (DS) for hybrids with significant specific combining ability (SCA) effects in at least one of the three environments: Gazipur, Benerpota and Kaliganj.

Parental combination	Gazipur		Benerpota		Kaliganj	
	DS	SCA effect	DS	SCA effect	DS	SCA effect
CZ-28×CZ-29	85	4.00**	87	1.58*	78	-0.98
CZ-28×BIL-65	79	-0.56	87	1.63*	77	-2.10*
CZ-28 × CZ-36	81	-0.67	86	-1.42*	81	0.88
CZ-28×CZ-12	77	-1.33	83	-1.48*	84	3.07**
CZ-28×CZ-26	85	1.00	88	0.58	79	-0.85
CZ-28×CZ-24	82	-1.17	86	-1.37*	79	-0.62
CZ-28×9MG	79	-1.28	87	0.47	79	0.60
CZ-29×BIL-65	81	-2.00	83	-2.98**	79	-0.82
CZ-29×CZ-36	85	-0.11	88	0.97	78	-1.85*
CZ-29×CZ-12	79	-3.11**	82	-2.75**	74	2.68**
CZ-29×CZ-26	88	0.22	89	1.30*	79	-0.90
CZ-29×CZ-24	88	1.39	91	2.69**	79	-0.68
CZ-29×9MG	83	-0.39	86	-0.81	82	2.54**
BIL-65×CZ-36	85	1.67	88	1.36*	80	-0.79
BIL-65×CZ-12	83	2.33*	88	3.30**	83	1.24
BIL-65×CZ-26	85	-0.67	86	-0.98	83	2.49**
BIL-65×CZ-24	85	0.17	87	-0.59	82	1.21
BIL-65×9MG	81	-0.94	85	-1.75**	78	-1.23
CZ-36×CZ-12	82	-0.11	87	0.91	81	-0.96
CZ-36×CZ-26	87	-0.78	89	-0.03	83	1.63
CZ-36×CZ-24	85	-2.28*	88	-1.31*	81	0.02
CZ-36×9MG	86	2.28*	88	-0.48	81	1.07
CZ-12×CZ-26	86	1.22	87	0.25	79	-2.68**
CZ-12×CZ-24	86	1.39	88	0.97	80	-1.62
CZ-12×9MG	81	-0.39	85	-1.20	79	-1.73*
CZ-26×CZ-24	89	-0.61	87	-2.64**	82	1.63
CZ-26×9MG	86	-0.39	90	1.52*	78	-1.32
CZ-24 × 9MG	87	1.11	91	2.25**	79	0.07

*Significant at $P < 0.05$. ** Significant at $P < 0.01$.

saline environments. The saline tolerant line CZ-24 emerged silk significantly lately but early at Kaliganj environment (Table 3).

Female flowering of the hybrids for the three environments averaged 84, 87, and 30 days at Gazipur, Benerpota and Kaliganj, respectively (Table 5). The SCA effects for tasseling varied and only one hybrid (CZ-29×CZ-12) was significant across the environment but positively became late at Kaliganj area. On the other hand, five hybrids in two of three environments showed significant SCA where only one (CZ-36×CZ-24) was negative and two (CZ-28×CZ-29 and BIL-65×CZ-12) were positive in both environments (Table 5). On the contrary, six hybrids were not significant in any of the environments. Unfortunately, among the early and late maturing hybrids, the involvement of saline susceptible or tolerant parents was not consistent which support the findings of Ahmed et al. (2008). The four pedigrees (CZ-28×CZ-24, CZ-29×BIL-65, BIL-65×9MG and CZ-12×9MG) demonstrated earliness across the environments with respect to SCA effects and were extreme in saline areas only. Therefore, these hybrids would be highly desirable for breeding objective regarding saline areas. Amiruzzaman et al. (2011) reported similar results in normal soil condition.

Anthesis silking interval

Regarding ASI none of the parents was a good general combiner as the GCA effects of any parent were not significant across the environments. The GCA of the saline susceptible parent CZ-28 was negative in all the three environments which need significantly minimum interval except for Benerpota area (Table 3). It established the notion that saline susceptibility contributes to early pollination within the same maize plant. However, the GCA effect for CZ-29 was positive in all environments

Table 6. Mean anthesis silking interval (ASI) for hybrids with significant specific combining ability (SCA) effects in at least one of the three environments: Gazipur, Benerpota and Kaliganj.

Parental combination	Gazipur		Benerpota		Kaliganj	
	ASI	SCA effect	ASI	SCA effect	ASI	SCA effect
CZ-28×CZ-29	2.67	0.53	11.33	0.26	4	-0.70
CZ-28×BIL-65	1.33	0.59	13.33	3.15**	4.33	0.16
CZ-28 × CZ-36	-1.00	-2.08*	7.67	-2.46*	6.50	1.08
CZ-28×CZ-12	0.33	-0.75	10.00	-0.13	6.67	1.38
CZ-28×CZ-26	1.67	-0.69	11.33	3.60**	1.83	-2.70**
CZ-28×CZ-24	2.67	0.81	3.00	-5.90**	4.67	0.60
CZ-28×9MG	2.67	1.59	13.00	1.48	5.00	0.19
CZ-29×BIL-65	4.67	0.53	9.00	-2.35*	5.17	-0.15
CZ-29×CZ-36	4.33	-0.13	13.00	1.71	4.33	-2.23**
CZ-29×CZ-12	4.33	-0.13	10.33	-0.96	7.17	0.74
CZ-29×CZ-26	5.00	-0.75	9.67	0.76	5.33	-0.34
CZ-29×CZ-24	5.33	0.09	10.67	0.60	5.50	0.30
CZ-29×9MG	4.33	-0.13	12.67	-0.02	8.33	2.38**
BIL-65×CZ-36	3.67	0.59	9.67	-0.74	5.83	-0.20
BIL-65×CZ-12	1.67	-1.41	13.33	2.93**	5.83	-0.06
BIL-65×CZ-26	4.33	-0.02	7.33	-0.68	8.33	3.19**
BIL-65×CZ-24	3.00	-0.86	6.00	-3.18**	4.50	-0.17
BIL-65×9MG	3.67	0.59	12.67	0.87	2.67	-2.76**
CZ-36×CZ-12	3.67	0.25	11.33	0.98	6.83	-0.31
CZ-36×CZ-26	4.67	-0.02	5.67	-2.29*	7.67	1.27
CZ-36×CZ-24	4.00	-0.19	14.33	5.21**	5.00	-0.92
CZ-36×9MG	5.00	1.59	9.33	-2.40*	8.00	1.33
CZ-12×CZ-26	7.33	2.64**	5.33	-2.63**	5.17	-1.09
CZ-12×CZ-24	4.00	-0.19	10.33	1.21	5.83	0.05
CZ-12×9MG	3.00	-0.41	10.33	-1.40	5.83	-0.70
CZ-26×CZ-24	6.67	1.20	7.67	0.93	5.17	0.13
CZ-26×9MG	2.33	-2.36*	9.67	0.32	5.33	-0.45
CZ-24×9MG	3.33	-0.86	11.67	1.15	5.33	0.02

*Significant at $P < 0.05$. ** Significant at $P < 0.01$.

and non-significant only in Kaliganj site that led to late pollination and ultimately poor yield for an individual plant.

None of the hybrids had significant SCA effects for all the three environments but most of the hybrids were non-significant across the environments (Table 6). The averaged anthesis silking intervals were 04, 10, and 06 days to ASI for Gazipur, Benerpota and Kaliganj, respectively, where the Benerpota site took maximum days to pollination. Late pollination may lead to inconsistent grain filling due to exposure to high temperature (Henry et al., 2014). The SCA effects were significant both in positive and negatively for only three hybrids in two of three environments (Table 6).

However, four hybrids (CZ-28×BIL-65, CZ-28×9MG, CZ-29×CZ-24, and CZ-26×CZ-24) had positive SCA effects in all of the three environments in which two saline susceptible parents are involved in three of the four hybrids but the parent CZ-28 that possessed negative GCA across the environments, could not contribute to shortening the pollination period in most of its hybrids. Ivy and Hawlader (2000) also reported that good general combining parents do not always show high SCA effects in their hybrid combinations. On the other hand, only two hybrids (BIL-65×CZ-24 and CZ-12×9MG) had negative SCA effects across the environments where none of their parents are saline susceptible. Iqbal et al. (2012) reported similar results in water stress condition.

Plant height

Plant height ranged between 108.1 to 180.3 cm with averages of 163.31, 153.40, and 168.52 cm for Gazipur, Benerpota, and Kaliganj, respectively (Table 7). Two lines, CZ-29 and BIL-65 exhibited significantly negative GCA on height in two environments where the dwarf line CZ-29 significantly decreased plant height by showing

Table 7. Mean plant height (PH) for hybrids with significant specific combining ability (SCA) effects in at least one of the three environments: Gazipur, Benerpota and Kaliganj.

Parental combination	Gazipur		Benerpota		Kaliganj	
	PH	SCA effect	PH	SCA effect	PH	SCA effect
CZ-28×CZ-29	154.2	6.43	160.9	26.24**	166.7	-1.47
CZ-28×BIL-65	141.1	-9.06*	108.1	-24.39**	158.7	-14.07**
CZ-28 × CZ-36	157.9	-5.04	162.9	2.67	170.6	5.88
CZ-28×CZ-12	173.5	9.95*	143.1	1.50	165.7	-4.38
CZ-28×CZ-26	172.1	1.29	161.8	-0.06	176.9	8.86*
CZ-28×CZ-24	168.7	-0.16	156.3	-3.25	179.2	6.45
CZ-28×9MG	158.5	-3.41	147.6	-2.71	163.8	-1.28
CZ-29×BIL-65	129.3	-10.99*	120.0	-4.85	178.8	6.97*
CZ-29×CZ-36	151.2	-1.89	148.2	-4.28	158.6	-5.12
CZ-29×CZ-12	148.8	-4.85	135.7	1.84	173.7	4.59
CZ-29×CZ-26	165.3	4.29	149.6	-4.51	146.9	-20.17**
CZ-29×CZ-24	163.0	4.03	143.6	-8.17	173.6	1.82
CZ-29×9MG	155.1	2.99	136.3	-6.26	177.5	13.38**
BIL-65×CZ-36	160.1	4.51	149.1	-1.33	156.4	-11.88**
BIL-65×CZ-12	151.2	-4.91	115.0	-16.74**	176.5	2.82
BIL-65×CZ-26	176.3	12.82*	171.2	19.16**	179.3	7.69*
BIL-65×CZ-24	166.9	5.44	170.0	20.29**	178.6	2.25
BIL-65×9MG	156.7	2.19	148.3	7.85	174.9	6.22
CZ-36×CZ-12	167.4	-1.48	160.9	1.41	166.6	1.01
CZ-36×CZ-26	173.8	-2.41	180.3	0.55	172.7	9.14*
CZ-36×CZ-24	175.6	1.41	175.0	-2.40	177.9	9.63**
CZ-36×9MG	172.2	4.89	171.6	3.39	151.9	-8.67*
CZ-12×CZ-26	177.1	0.30	161.9	0.84	172.7	3.75
CZ-12×CZ-24	176.4	1.66	164.1	5.31	160.1	-13.53**
CZ-12×9MG	167.2	-0.67	155.4	5.84	171.7	5.74
CZ-26×CZ-24	170.7	-11.34*	169.2	-9.82	171.4	-0.25
CZ-26×9MG	170.3	-4.94	163.6	-6.16	154.9	-9.02*
CZ-24×9MG	172.1	-1.04	165.5	-1.96	162.3	-6.37

*Significant at $P < 0.05$. **Significant at $P < 0.01$.

significant GCA of -12.72 and -13.24 cm in Gazipur and Benerpota locations but non-significantly by -0.64 cm at Kaliganj area in high salinity (Table 3). Conversely, the tall line CZ-24 significantly increased plant height by showing positive GCA of 8.37, 11.66 and 3.91 in the study environments. GCA effects of the two tall and saline susceptible lines (CZ-26 and CZ-28) were contrary regarding plant height where CZ-28 shortens height in Gazipur and Benerpota locations but CZ-26 significantly increased plant height in those locations. Four of the eight parents significantly decreased plant height in Benerpota site. Identifying lines with negative GCA would be beneficial for a breeding objective of reducing the plant height. Structurally, shorter plants would be less likely to lodge.

SCA effects of the hybrids were mostly non-significant over the environments but in Kaliganj site, they were comparatively short. With CZ-28×BIL-65, tall, saline susceptible and medium tall, medium saline tolerant lines respectively, resulted in short hybrids by negative SCA of 9.06 to 24.39 cm in all locations. Again BIL-65 with another tall and saline susceptible CZ-26 line produced tall hybrids by showing positive and significant SCA of 7.69 to 19.16 cm over the environments. Besides these, in most cases, CZ-28 with other parents resulted in tall plants, but CZ-26 and BIL-65 appear to be malleable with respect to plant height because they appeared as parents responsible for both positive and negative SCA effects when crossed with other parents. Moreover, CZ-26 and CZ-24 resulting in shorter plants in all locations when used as female parents (Table 7). Therefore, these two lines may be taken into consideration for breeding dwarf or tall maize plants. Considering crosses between tall lines, there were fluctuations of plant height and none of the crosses gave taller hybrids across the environments but four crosses viz. CZ-28×9MG, CZ-26×CZ-24, CZ-26×9MG, and CZ-24×9MG were exceptional where they produced shorter plants in all the environments. The

Table 8. Mean 100-grain weight (100-GW) for hybrids with significant specific combining ability (SCA) effects in at least one of the three environments: Gazipur, Benerpota and Kaliganj.

Parental combination	Gazipur		Benerpota		Kaliganj	
	100-GW	SCA effect	100-GW	SCA effect	100-GW	SCA effect
CZ-28×CZ-29	38.67	-1.60	24.33	-2.18	24.67	-3.92**
CZ-28×BIL-65	36.67	0.34	24.33	-1.57	30.67	2.86**
CZ-28 × CZ-36	36.33	0.12	26.00	-0.96	23.67	-4.70**
CZ-28×CZ-12	38.67	0.23	29.00	0.60	35.00	3.30**
CZ-28×CZ-26	34.33	-2.27	28.67	1.37	30.00	0.97
CZ-28×CZ-24	37.00	2.40	27.67	3.10**	29.67	2.13**
CZ-28×9MG	40.33	0.79	27.00	-0.35	28.00	-0.64
CZ-29×BIL-65	42.67	3.90*	32.33	5.82**	32.67	4.08**
CZ-29×CZ-36	34.67	-3.99*	21.00	-6.57**	27.67	-1.48*
CZ-29×CZ-12	41.33	0.45	33.00	3.98**	37.00	4.52**
CZ-29×CZ-26	38.67	-0.38	31.67	3.76**	31.67	1.86**
CZ-29×CZ-24	39.33	2.29	24.67	-0.52	26.67	-1.64**
CZ-29×9MG	41.33	-0.66	23.67	-4.29**	26.00	-3.42**
BIL-65×CZ-36	32.00	-2.71	21.67	-5.29**	22.67	-5.70**
BIL-65×CZ-12	33.33	-3.60*	26.00	-2.40*	28.67	-3.03**
BIL-65×CZ-26	38.00	2.90	29.67	2.37*	31.00	1.97**
BIL-65×CZ-24	33.00	-0.10	28.33	3.76**	31.00	3.47**
BIL-65×9MG	37.33	-0.71	24.67	-2.68*	25.00	-3.64**
CZ-36×CZ-12	43.33	6.51**	36.33	6.87**	38.00	5.75**
CZ-36×CZ-26	36.00	1.01	29.33	0.98	30.00	0.41
CZ-36×CZ-24	31.33	-1.66	27.67	2.04	30.00	1.91**
CZ-36×9MG	38.67	0.73	31.33	2.93**	33.00	3.80**
CZ-12×CZ-26	33.33	-3.88*	24.00	-5.79**	25.67	-7.25**
CZ-12×CZ-24	34.67	-0.55	22.67	-4.40**	28.00	-3.42**
CZ-12×9MG	41.00	0.84	31.00	1.15	32.67	0.13
CZ-26×CZ-24	34.00	0.62	21.00	-4.96**	26.67	-2.09**
CZ-26×9MG	40.33	2.01	31.00	2.26*	34.00	4.13**
CZ-24×9MG	33.33	-2.99	27.00	0.98	28.00	-0.37

*Significant at $P < 0.05$. ** Significant at $P < 0.01$.

higher variation in plant height was found due to the environmental influence in some studies (Mickelson et al., 2001; Murtadha et al., 2018). In another study, GCA effect for plant height was found more stable over the environments than yield (Henry et al., 2014). A positive relation between maize yield and plant height was found by Farfan et al. (2013). However, crosses between dwarf lines, only one cross CZ-29×CZ-36 was able to produce a shorter hybrid over the locations. The GCA for CZ-29 was also negative in all locations. Ahmed et al. (2014) in their study also found line(s) as good general combiner responsible for short plant type.

100-Grain weight

GCA effects of the parents were not consistent over the environments except for BIL-65, CZ-24, and CZ-12. The saline tolerant line CZ-12 increased grain weight with positive GCA of 0.958 to 3.01 in all study environments and exhibited significantly positive GCA on 100GW in two environments (Table 3). Highly significant and positive GCA effects for 100-grain weight was observed by Ahmed et al. (2014), Alam et al. (2008) and Abdel-Moneam et al. (2009). Conversely, another saline tolerant line CZ-24 demonstrated significantly negative GCA across the environments and reduced grain weight by 1.15 to 2.87 g. Medium salt tolerant line BIL-65 also decreased grain weight by 0.71 to 1.15 g in Gazipur and Benerpota locations but significantly by 0.86 g at Kaliganj area in high salinity. It is remarkable that all the parents except CZ-12 and CZ-26 decreased grain weight in increased salinity at Kaliganj locations where CZ-12 is saline tolerant and CZ-26 susceptible. Hundred grain weight ranged between 21.0 to 43.33 g with averages of 37.13, 27.32, and 29.56 g for Gazipur, Benerpota, and Kaliganj, respectively (Table 8). Only two crosses CZ-29 x BIL-65 and CZ-36 x CZ-12 possessed significant positive SCA across the environments and successfully increased grain weight where all the parents involved in these crosses are saline tolerant. Likewise, three crosses, CZ-29×CZ-36, BIL-65×CZ-12 and CZ-12×CZ-26 of which all the parents barring CZ-26 are saline tolerant unlikely exhibited significantly negative SCA for grain weight in all the environments. Therefore, the involvement of saline tolerant parents to produce hybrids with higher grain weight in saline areas is agitated in this study. But considering the two crosses CZ-29×BIL-65 and CZ-29×CZ-36 which produced contrary SCA effects for grain weight, the line BIL-65 responsible for increased grain weight in these crosses with the same female parent, may be considered as a favorable parent for breeding objective with bold seeded maize development. Besides these five hybrids, there are another seven hybrids those have significant positive SCA effects for producing bold seeded maize in the two saline areas and these hybrids are mostly generated by saline tolerant parents (Table 8). However, under saline condition such results were not found in maize or other crops, although Iqbal et al. (2012) reported similar results in maize under water stress condition.

Yield

GCA effects for grain yield were positive and significant in at least two of the three environments for two entries: CZ-29 and CZ-26 (Table 3). Positive GCA effects represent parental lines that increased grain yield across all hybrids on average. Conversely, GCA effects for grain yield were negative and significant in at least two of the three locations for only one parent: CZ-12 (Table 3). CZ-29 and CZ-26 performed well in both saline environments but were not so good at Gazipur. Moreover, in Gazipur location, none of the parents exhibit either significantly positive or negative GCA where, three parents: CZ-12, CZ-36 and 9MG had a negative effect on grain yield. The only saline tolerant parent, CZ-12 had significantly decreased yield in both the saline sites and non-significantly in the normal environment at Gazipur. The lines CZ-28, CZ-36, and CZ-24 exhibited inconsistent grain production both in normal and saline environments. The results of the present study are unexpected because none of the saline resistant lines included in this study consistently contributed to increase grain production. Moreover, a tolerant line like CZ-12 decreased yield where a susceptible line, CZ-26 increased yield. Again, among the good combiner parents, CZ-29 was shorter and early flowering while CZ-26 was taller and had late flowering but both significantly increased grain yield in saline environments (Table 3) but Barrero Farfan et al. (2013) observed a mild, positive relationship between yield and plant height. Therefore, the nature of the contribution in promoting yield of these parents is unpredictable.

Grain yield ranged between 3.02 and 8.36 t ha^{-1} with averages of 5.90, 4.16, and 4.81 t ha^{-1} for Gazipur, Benerpota, and Kaliganj, respectively (Table 9). Performance of most of the crosses was inconsistent over the locations. The highest yielding entry within a given environment was CZ-26×9MG (8.36 t ha^{-1}) at Gazipur. The lowest yielding entry within a given environment was with BIL-65×CZ-12 (3.02 t ha^{-1}) at Benerpota. Unexpectedly, the yield at Benerpota area; the excessive saline zone, was below average for all the crosses except CZ-29×CZ-36 which yielded 5.25 t ha^{-1} with significant and positive SCA but was low yielder: 5.27 and 4.49 t ha^{-1} at Gazipur and Kaliganj locations respectively having significant negative SCA at Kaliganj site. The SCA effects for yield at Gazipur were significant and positive for CZ-26×9MG and CZ-26×CZ-24 that were the best yielder (8.36 and 7.77 t ha^{-1} respectively) in this location (Table 9). Again, these two crosses CZ-26×CZ-24 and CZ-26×9MG were the highest (6.99 t ha^{-1}) and 5th by yield (5.49 t ha^{-1}) respectively at Kaliganj environment and also possessed significantly positive SCA effects, whereas they accompanied negative SCA at Benerpota environment and gave poor yield. On the other hand, CZ-29×BIL-65 the most consistent and promising hybrid over the environments ranked 2nd at Benerpota (4.81 t ha^{-1}) and Kaliganj (6.73 t ha^{-1}) and 3rd at Gazipur (7.40 t ha^{-1}) location for yield having significant positive SCA effects at Gazipur and Kaliganj. Again, CZ-29×CZ-12, CZ-29×9MG, CZ-28×CZ-36 and BIL-65×CZ-36 also gave consistent yield in all environments with positive SCA effects though they were not so good yielder in their respective site (Table 9). Therefore, CZ-26 and CZ-29 worked especially well for grain yield when used as female parents. It was expected to see CZ-26 and CZ-29 do well because their individual GCA effects revealed the potential for enhanced combining ability for grain yield (Table 3). Conversely, the combined effect of these two lines CZ-29 x CZ-26 were not useful as parents in crosses to boost grain yield, as their resulting hybrid consistently decreased yield over locations with significant negative SCA effects at Gazipur and Kaliganj sites. Another six hybrids CZ-28×CZ-29, CZ-29×CZ-26, BIL-65×CZ-12, CZ-36×CZ-26, CZ-36×CZ-24, and CZ-24×9MG also consistently decreased yield over locations bearing significant negative SCA effects at least one site in each case where CZ-12, CZ-24 and CZ-36 are saline tolerant lines. None of the hybrids generated by both saline tolerant parents was able to give a constantly higher yield over locations but their contribution was contrary. However, no other report was found showing the relationship of salinity stress on maize under multilocation. Hence the influence of varying salinity level on maize production needs further intensive studies to correlate the role of tolerant maize varieties on higher yield potential. A comprehensive genetic study is a prerequisite to determine the nature of inheritance of a trait that will lead to choose the right breeding improvement strategy for the crop (Azad et al., 2014). As

Table 9. Mean grain yield (t ha^{-1}) for hybrids with significant specific combining ability (SCA) effects in at least one of the three environments: Gazipur, Benerpota and Kaliganj.

Parental Combination	Gazipur		Benerpota		Kaliganj	
	Yield	SCA effect	Yield	SCA effect	Yield	SCA effect
CZ-28×CZ-29	5.48	-0.48	3.48	-0.66**	4.65	-0.49
CZ-28×BIL-65	6.31	0.34	3.18	-0.55**	5.11	0.40
CZ-28 × CZ-36	6.73	0.87	4.12	0.10	6.48	1.65**
CZ-28×CZ-12	5.29	-0.37	4.08	0.49*	3.34	-0.94**
CZ-28×CZ-26	6.74	0.64	4.36	0.40*	4.61	-0.47
CZ-28×CZ-24	5.54	-0.80	3.95	0.27	4.51	-0.62
CZ-28×9MG	5.30	-0.21	3.68	-0.05	4.69	0.48
CZ-29×BIL-65	7.40	1.40**	4.81	0.33	6.73	1.59**
CZ-29×CZ-36	5.27	-0.61	5.25	0.48*	4.49	-0.77*
CZ-29×CZ-12	5.92	0.23	4.55	0.21	5.08	0.37
CZ-29×CZ-26	3.81	-2.32**	4.44	-0.26	3.89	-1.63**
CZ-29×CZ-24	6.95	0.58	4.34	-0.08	6.19	0.63
CZ-29×9MG	6.73	1.19*	4.47	0.00	4.94	0.30
BIL-65×CZ-36	7.31	1.41**	4.56	0.21	4.96	0.12
BIL-65×CZ-12	5.41	-0.29	3.02	-0.91**	3.42	-0.86*
BIL-65×CZ-26	4.99	-1.16*	4.72	0.43*	4.36	-0.72*
BIL-65×CZ-24	6.26	-0.12	4.19	0.17	5.04	-0.09
BIL-65×9MG	3.96	-1.59*	4.40	0.33	3.77	-0.44
CZ-36×CZ-12	6.62	1.03*	3.68	-0.53**	4.80	0.40
CZ-36×CZ-26	3.71	-2.32**	4.51	-0.06	4.84	-0.37
CZ-36×CZ-24	6.18	-0.09	4.00	-0.30	4.35	-0.90**
CZ-36×9MG	5.14	-0.30	4.44	0.10	4.20	-0.12
CZ-12×CZ-26	7.04	1.21*	4.05	-0.10	5.45	0.80*
CZ-12×CZ-24	5.63	-0.45	4.43	0.56**	5.14	0.43
CZ-12×9MG	3.88	-1.36**	4.19	0.27	3.59	-0.19
CZ-26×CZ-24	7.77	1.26*	4.05	-0.19	6.99	1.48**
CZ-26×9MG	8.36	2.68**	4.07	-0.21	5.49	0.91**
CZ-24×9MG	5.52	-0.40	3.57	-0.43*	3.69	-0.94**

*Significant at $P < 0.05$. ** Significant at $P < 0.01$.

salinity is an environmental factor affecting polygenic trait it needs a detailed genetic study to investigate the relationship with maize yield and yield contributing characters. Since under saline condition such information is not availablr so far, the findings will be usefull to develop saline tolerant hubrids for saline soil.

Conclusion

In conclusion, CZ-29 and CZ-26 had positive and significant GCA effects for yield in both the saline environments and in Gazipur they were positive but non-significant. This is especially desirable from the breeding perspective to improve yield. Of the saline tolerant lines evaluated, CZ-29 was a good source for increased yield with significant and positive GCA values in both the saline environments that was also responsible for dwarfness and earliness in all locations, where CZ-12 possessed significantly negative GCA effects for yield in both the saline areas and non-significantly negative in Gazipur, though it was a saline tolerant line. Hybrid CZ-29×BIL-65 however, was consistent and promising over the environments for bold seed and higher yield that ranked 2nd at Benerpota (4.81 t ha^{-1}) and Kaliganj (6.73 t ha^{-1}) and 3rd at Gazipur (7.40 t ha^{-1}) location for yield. Another four hybrids CZ-28×CZ-36, CZ-29 x CZ-12, CZ-29×9MG, and BIL-65×CZ-36 also gave consistent yield in all environments with positive SCA while, six hybrids CZ-28×CZ-29, CZ-29×CZ-26, BIL-65×CZ-12, CZ-36×CZ-26, CZ-36×CZ-24, and CZ-24×9MG consistently decreased yield over locations bearing significant negative SCA effects at least one of the three locations. None of the hybrids possessed all or most of the desirable traits across the environments. Among the early or late maturing and dwarf or tall hybrids, the involvement of either saline susceptible and tolerant or tall and dwarf parents were unpredictable. However, crosses between dwarf lines, only one cross CZ-29×CZ-36 was able to produce a shorter hybrid over the locations. Therefore, among the lines evaluated in this diallel cross, CZ-28 and CZ-29 contributed to earliness; CZ-29 and BIL-65 reduced plant height; CZ-12 increased seed size; CZ-26 and CZ-29 improved yield but in most cases, these parents were unable to reflect their efficacy to the offspring they produced. Nevertheless, these lines might deserve an important consideration for broadening the germplasm base and pyramiding genes for earlier maturity, shorter plant height, increased seed size and improved yield.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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