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General and Specific combining ability studies for ear traits in maize (*Zea mays* L.)

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Abstract
An investigation was carried out to assess the combining ability in maize genotypes using a diallel mating design (without reciprocal crosses) using 6 homozygous lines namely, DMIT 121, DMIT 123, DMIT 124, DMIT 125, DMIT 113 and DMIT 118. The experiment was set up in a randomized complete block design (RCBD) with 3 replications during *kharif* season of 2016-17 in maize research centre, Devihosur, Haveri district, which comes under UAS, Dharwad, Karnataka.
ysis revealed presence of higher magnitude of SCA variance than GCA variance indicating predominance of non-additive gene action for all the ear traits. General combining ability studies revealed that DMIT 123 was best general combiner for major ear traits cob length, kernel rows per cob and kernels per row and the line DMIT 118 was best combiner for cob length, cob girth and kernels per row. The line DMIT 125 is best general combiner for cob length hence, these lines are used in various hybrid breeding programmes to increase maize grain yield with superior ear traits. However, the estimates of specific combining ability showed the desirable SCA effects in crosses DH 1514(DMIT 125 × DMIT 118) and DH 1509(DMIT 123 x DMIT 118) for all the ear traits including cob length, cob girth, kernel rows per cob, and kernels per row,. As these crosses having one of their parents with good general combiner for all the traits having H x L or L x H GCA status showing dominance and epistatic interactions.

Keywords: General combining ability (GCA), Specific combining ability (SCA), Diallel mating.

Introduction
Maize (*Zea mays* L.), a poaceae family member, is an important cereal crop of the world as well as Indian agricultural economy and ranks third next to wheat and rice in production and known as "Queen of cereals" due to its highest average grain yield. However, the average productivity of Indian cultivars is half of the world average productivity (Anon., 2017) [3] so there is ample scope for plant breeders to increase the productivity of Indian cultivars.
In any hybrid breeding programme choosing of the appropriate parents is important to exploit significant heterosis for economic traits. So, selection should be based on *per se* performance and combining ability of the parents. The genetic architecture of yield can be better understood through the application of biometric principles, several biometrical methods give information on the combining ability status of parental lines. One of the techniques widely used is Diallel analysis developed by Griffing (1956) [7]. This analysis provides reliable information on magnitude of additive and non-additive components based on general and specific combining ability effects of parents and their hybrid combinations.
Combining ability studies provide information on the relative importance of *gca* and *sca* variance for interpreting the genetic basis of important traits. This helps us to assess the nature of gene action and in identifying superior parental lines for their *per se* performance. The best combinations with general combining ability of individual lines are helpful to get more desirable recombinants which enables for further improvement of the crop. Hence, this investigation was undertaken to study the estimates of general and specific combining ability for ear traits in maize.

Materials and Methods
Experimental material
The present experiment was carried out at during summer 2015 and *kharif* 2016 at Maize research centre, Devihosur, comes under University of Agricultural Sciences, Dharwad, by involving six diverse inbred lines *viz.*, DMIT 121, DMIT 123, DMIT 124, DMIT 125, DMIT 113 and DMIT 118 developed by maize scheme at Main Agricultural Research Station, University of Agricultural Sciences Dharwad. The list of inbred lines and their pedigree were presented in Table 1.

The six elite inbred lines of maize are crossed in all possible combinations in half diallel method (without reciprocals) Model I, Method II suggested by Griffing 1956 [7]. This method of combining analysis includes one way crosses and their parents. This method is used when reciprocal differences are not significant. This is most commonly used method of combining ability analysis from a diallel cross.

Table 1: List of parental/inbred lines used in the study with their source/origin

Sr. No.	Inbred lines	Pedigree	Source/origin
1	DMIT 121	NS × 052030-X-X-X-X-11	MARS, Dharwad
2	DMIT 123	NK 6240 × CML 451-X-X-X-X-37	MARS, Dharwad
3	DMIT 124	NK6240 × CML 147-X-X-X-X-7	MARS, Dharwad
4	DMIT 125	CML 414× CML468-X-X-X-X-19	MARS, Dharwad
5	DMIT 113	D9081-7-5-18-26	MARS, Dharwad
6	DMIT 118	30V92 × K145-X-X-X-23	MARS, Dharwad

CML: CIMMYT Maize line MARS: Main Agricultural Research Station Dharwad

Experimental Method

Evaluation of F_1 hybrids was done by raising fifteen single cross hybrids along with six parents during *kharif* 2016 in Randomized complete block design (RCBD) with three replications to estimate the combining ability for ear traits. Each genotype was planted in two rows with plot size 4.0 x 1.2 meters. The spacing between rows and plants maintained 60cm and 30cm respectively. One plant per hill was maintained and recommended package of practices was followed to raise a healthy crop. Observations recorded on maize grain yield and its contributing traits such as cob length (cm), cob girth (cm), Number of kernel rows per ear and Number of kernels per row were recorded on five random plants from each plot.

Mean data was subjected for analysis of general combining ability (GCA) and specific combining ability (sca) as per method II and model I given by Griffing (1956) [7] using the software WINDOSTAT (version 7.1).

Results and Discussion

Analysis of variance for combining ability was carried out for yield and its components and the mean sum of squares which are presented in Table 2. The mean squares due to gca and sca were highly significant for all the traits. This suggested that both the additive and non-additive gene action were important for the expression of these traits. The estimates variance due to S was found to be higher than the variance due to gca for all studied characters. The magnitude GCA to SCA variance for the characters *viz.*, cob length (0.04), cob girth (0.04), kernel rows per cob (0.35) and kernels per row (0.03) was lesser than unity showed preponderance of non-additive gene action.

The general combining ability (GCA) effects of parents of maize for ear traits were estimated and presented in Table 3. The estimate of gca effects exhibited that the parent line DMIT 123 considered as best general combiner for most studied ear traits *i.e.* cob length, cob girth, kernel rows per cob, kernels per row and the parent DMIT 118 exhibited desirable GCA effects for cob length, kernel rows per cob and kernels per row So, these parents could be used extensively in hybrid breeding programme to increase maize grain yield with superior ear traits. Similar results were also reported for the characters *i.e*. cob length (Rather *et al*., 2009, Mohammad *et al*., 2013 and Azad *et al*., 2014) [14, 9, 5], cob girth (Prodhan and Rai 1999, Mohammad *et al*., 2013, Mousa., 2014 and Zeleke 2015) [13, 9, 10, 16], kernel rows per cob (Packiaraj., 1995 and Mohammad *et al.*, 2013) [11, 9] and kernels per row (Premalatha *et al*., 2011 and Abuali *et al*., 2012) [12, 1].

The specific combining ability (SCA) effects of crosses of maize for ear traits were estimated and presented in Table 4. The SCA effects represent mainly dominance, additive × dominance, dominance × dominance effects. The crosses showing SCA effects involving parents with good GCA could be exploited. The highest SCA effects for cob length were obtained in the cross DH 1505 (DMIT 121 × DMIT 118) with parents involving low × high GCA and in the cross DH 1501 (DMIT 121 × DMIT 123) with parents involving low × high GCA effects. The hybrids DH 1509 (DMIT 123 × DMIT 118), DH 1504 (DMIT 121 × DMIT 113) and DH 1506 (DMIT 123 × DMIT 124) had high SCA effects with GCA combination of H × H, L × L and H × L, respectively for cob girth. The results are total agreement with the results of Premalatha *et al*. (2011) [12], Zeleke (2015) [16] and Aslam *et al*. (2017) [4] for Cob length. Debnath and Sarkar (1987) [6], Jayakumar and Sundaram (2007) [8], Rather *et al*. (2009) [14], Premalatha *et al*. (2011) [12] and Aslam *et al*. (2017) [4] for Cob girth.

The crosses DH 1509 (DMIT 123 × DMIT 118), DH 1505 (DMIT 121 × DMIT 118) and DH 1514 (DMIT 125 × DMIT 118) reported significant higher SCA effects for kernel rows per ear with GCA combination of parents H × H, L × H and L × H, respectively. As these hybrids possess atleast one parent as good general combiner for this trait. Similar results reported by Alamine *et al*. (2003) [2], Todkar *et al*. (2006), Zeleke (2015) [16], Talukder *et al*. (2016) and Aslam *et al.* (2017) [4].

Crosses *viz*., DH 1509 (DMIT 123 × DMIT 118), DH 1501 (DMIT 121 × DMIT 123) and DH 1507 (DMIT 123 × DMIT 125) exhibited significant SCA effects in positive direction. Here, all the three crosses possess good general combiner as their parent to give best parental combinations. It was note that very high proportion of genetic variance indicating the importance of non-additive gene action in the inheritance of this character which is in agreement with the reports of Alamine *et al.* (2003) [2], Jaykumar and Sundaram (2007) [8], Zeleke (2015) [16], Talukder *et al*. (2016) and Aslam *et al*. (2017) [4].

A close observation of data on top hybrids showing higher SCA effects for ear traits indicates that the crosses exhibiting significant high SCA effects for ear traits enhances maize grain yield with higher SCA effects. Overall results revealed that different crosses exhibited differential response for SCA effects for all the quantitative traits *i.e.*, there were very little or no reproducibility for SCA effects of the crosses.

Table 2: ANOVA for combining ability for different ear traits in 6 × 6 half diallel set of maize hybrids

Character	Cob length	Cob girth	Kernel rows per cob	Kernels per row	Grain yield
GCA	4.08**	0.10**	5.73**	15.94**	88.28*
SCA	10.99**	0.29**	2.09**	58.34**	717.85**
Error	0.36	0.01	0.10	1.24	48.130
GCA Variance	0.46	0.01	0.70	1.83	52.01
SCA Variance	10.63	0.28	1.98	57.09	669.72
GCA Variance/SCA Variance	0.04	0.04	0.35	0.03	0.07

* and** - significance at 0.05 and 0.01 level for probability, respectively.

Table 3: Estimation of *gca* effects of parents for different ear traits in 6 × 6 half diallel set of maize hybrids

Parents	Cob length	Cob girth	Kernel rows per cob	Kernels per row
DMIT 121	0.05	0.02	0.15	-1.34**
DMIT 123	1.04**	-0.11**	1.04**	2.29**
DMIT 124	-0.55**	-0.12**	-1.51**	-0.10
DMIT 125	-0.78**	0.02	0.4**	-0.36
DMIT 113	-0.38	0.02	-0.09	-1.38**
DMIT 118	0.61**	0.19**	0.08	0.90*
S. Em. ±	0.19	0.04	0.10	0.36
CD (g_i) @ 5 %	0.49	0.10	0.27	0.92
CD(g_i) @ 1 %	0.77	0.16	0.41	1.43

* and** - significance at 0.05 and 0.01 level for probability, respectively.

Table 4: Estimation of SCA effects of crosses for different ear traits in 6 × 6 half diallel set of maize hybrids

Experimental hybrids	Cob length	Cob girth	Kernel rows per cob	Kernels per row
DH 1501(DMIT 121 × DMIT 123)	3.11**	0.26*	-0.15	6.63**
DH 1502(DMIT 121 × DMIT 124)	1.15*	0.26*	0.13	2.70*
DH 1503(DMIT 121 × DMIT 125)	1.84**	0.33**	0.94**	0.82
DH 1504(DMIT 121 × DMIT 113)	0.983	0.42**	-1.02**	3.78**
DH 1505(DMIT 121 × DMIT 118)	3.11**	0.35**	2.08**	5.36**
DH 1506(DMIT 123 × DMIT 124)	0.69	0.38**	0.44	2.52*
DH 1507(DMIT 123 × DMIT 125)	2.54**	0.22	-0.14	6.05**
DH 1508(DMIT 123 × DMIT 113)	1.62**	0.23*	-0.44	2.01
DH 1509(DMIT 123 × DMIT 118)	2.68**	0.53**	2.25**	9.18**
DH 1510(DMIT 124 × DMIT 125)	1.18*	0.17	0.21	2.78*
DH 1511(DMIT 124 × DMIT 113)	1.32*	0.37**	0.24	1.67
DH 1512(DMIT 124 × DMIT 118)	1.32*	0.18	0.14	2.85*
DH 1513(DMIT 125 × DMIT 113)	-0.11	-0.04	-1.94**	4.66**
DH 1514(DMIT 125 × DMIT 118)	1.31*	0.31*	1.28**	3.44**
DH 1515(DMIT 113 × DMIT 118)	2.34**	0.16	0.45	3.06**
CD (S_{ij}) @ 5 %	1.14	0.23	0.62	2.12
CD (S_{ij}) @ 1 %	1.57	0.32	0.85	2.93

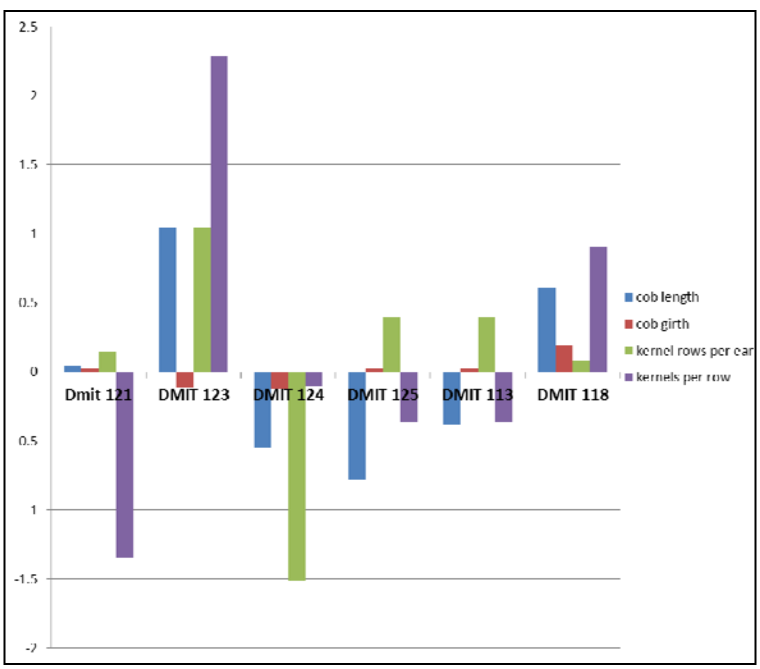

Fig 1: GCA effects of parents for different ear traits

Conclusion

The parental lines DMIT 123 and DMIT 118 were the best among 6 parents as it showed desirable mean and GCA effects for most of the ear traits. Therefore these parents could be used extensively in hybrid breeding programme with a view to increase maize grain yield. Hence, these high yielding parents with good attributes for different yield components may be intercrossed to pool the genes in desirable direction to improve yield potential. Furthermore, based on SCA effects two hybrids DH 1509 (DMIT 123 × DMIT 118) and DH 1506 (DMIT 123 × DMIT 118) were proved to be the best crosses to increase maize grain yield. For varietal improvement, these crosses could also be utilized for exploiting promising recombinants and it could be useful towards enhancing maize grain yield.

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