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Research Note

Combining ability studies for grain yield and quality parameters in newly developed maize (*Zea mays* L.) inbred line crosses

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Abstract
Studies on combining ability were carried out at maize scheme, MARS, University of Agricultural Sciences, Dharwad, during *Kharif* 2011 for grain yield and quality parameters *viz.,* protein and starch content in 91 single cross hybrids developed using 14 x 14 diallel set (excluding reciprocals). The combining ability analysis revealed the presence of higher magnitude of SCA than GCA variance for all characters under study. The ratio of additive to dominance variance was lower than unity for all traits, indicating higher non additive variance than additive variance. Eight cross combinations were found as good specific combiners for grain yield along with protein and starch content. Among the 14 parents, inbred lines namely DMIL 9 and DMIL 5 were found to be the best parents for grain yield, however, the parents namely DMIL 14, DMIL 11, DMIL 10 and DMIL 3, DMIL 12 were found superior for protein and starch content.

Keywords
Zea mays L. , diallel, combining ability, grain yield, quality parameters.

Maize is the most important cereal crop in the world. Although maize is mainly considered as source of carbohydrates (Krishnaveni, 1983) but it is also important source of protein because of its total protein yield per hectare (Mohan Lal *et al.,*2011) . It was demonstrated that increase of protein per cent could possible by breeding (Woodworth *et al*., 1952). The concept of general and specific combining ability was introduced by Sprague and Tatum (1942) and its mathematical model was set about by Griffings (1956). The value of any population depends on its potential *per se* and its combining ability in crosses (Vacaro *et al*., 2002). The usefulness of these concepts for the characterization of an inbred in cross has been increasingly popular among the maize since the last few decades. The knowledge of gene action and combining ability analysis helps in identifying the best combiners which may be hybridized either to exploit heterosis or to accumulate genes through selection and in understanding the characters to choose the proper selection method to be followed in breeding programmes. In view of this, present investigation was undertaken to study the combining ability effects, by evaluating the 91 single cross hybrids, developed using 14 x 14 diallel design for grain yield and quality parameters *viz*., protein and starch content.

The experimental material for the present investigation comprised of 14 newly developed inbred lines *viz.*, DMIL 1,DMIL 2, DMIL 3, DMIL 4, DMIL 5, DMIL 6, DMIL 7, DMIL 8, DMIL 9, DMIL 10, DMIL 11, DMIL 12, DMIL 13 and DMIL 14, 91 cross combinations and with 16 checks. The 91 single cross hybrids were developed by crossing 14 newly developed inbred lines in diallel mating design as suggested by Griffings excluding reciprocals during summer 2010 at MARS, University of Agricultural Sciences, Dharwad (Karnataka). The experimental material was grown in lattice square design with two replications. Each genotype was planted in two rows of 3 meter length with row to row and plant to plant spacing 60cm and 30cm , respectively. The observations, grain yield (q/ha) and two quality parameters *viz.*, protein content and starch content were recorded on five randomly selected plants in each plot. Data were analysed as per Griffings method II and model I to estimate combining ability effects. The protein content was estimated using Micro- Kjeldahl Method (Jackson,1967) and expressed in percentage. The starch content was estimated using anthrone reagent (Sadasivam and Manikam 1992) and expressed in percentage.

In the present investigation, analysis of variance (ANOVA) was carried out for three characters under study from the data obtained through diallel crosses. F test was conducted to examine the significance of variance. Mean sum of squares for three characters are presented inTable 1 and the combining ability analysis showed significant difference with respect to mean sum of squares due to general and specific combining ability effects indicating that both additive and non additive gene actions involved in the inheritance of grain yield, protein content and starch content. The analysis of GCA and SCA variances showed that 3 characters studied where controlled predominantly by non-additive gene actions (Table 2). These results are in concurrence with investigation carried out by earlier researchers Bjarnason *et al*. (1992), Gautam (2003), Bhatnagar *et al*. (2004) and Shanthi *et al* (2011).

Among the fourteen parents studied, the parental lines DMIL 9 and DMIL 5 can be given the status of good general combiners for grain yield and genetically worthy parents. These two parents expressed highest significant values of GCA effects and contributing maximum favourable genes for grain yield. Where as, five parents *viz.*, DMIL 14, DMIL 11, DMIL 10 and DMIL 3, DMIL 12 are found to be good general combiners with significant GCA effects along with along with higher *per se* values for protein and starch content (Table 3 and 4). Hence, these five parents can be better utilized for improvement of protein and starch. Similar studies were previously carried out by Prasad *et al*. (1988) and Venkatesh *et al*. (2001).

Out of 91 single crosses studied, 10 combination recorded high grain yield viz., 9 x 5 followed by 10 x 7, 4 x 3, 8 x 7, 14 x 10, 11 x 5, 9 x 8, 14 x 5, 9 x 4, 8 x 4 (Table 3 and 5), and hence can be proceed further in the breeding programme as either both the parents as good combiners or one of the parents as good combiner for either grain yield or quality parameters. These are also having significant sca. Among these 10 best specific combiners for grain yield, five crosses, namely, 9 x 5, 10 x 7, 4 x 3, 14 x 10, 11 x 5, 9 x 8, 14 x 5 and 9 x 4 were good specific combiners for protein and starch content along with yield (Table 4).

In brief, from the present investigation, it could be inferred that the parents DMIL 9 and DMIL 5 were adjudged as best parents for grain yield, while parents DMIL 14, DMIL 11, DMIL 10 AND DMIL 3, DMIL 12 for protein and starch content . Out of 91 single crosses studied, the cross combinations *viz.*, 9 x 5, 10 x 7, 4 x 3, 14 x 10, 11 x 5, 9 x 8, 14 x 5 and 9 x 4 were found to be good specific combiners for grain yield and along with protein and starch content and it was suggested that they could be exploited by production of single cross hybrids in realizing their high yield potential along with good quality.

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Table 1. Analysis of variance for 15 traits in half diallel crosses in maize

Sources	DF	Protein content (%)	Starch content (%)	Grain yield (q/ha)
Replicates	1	0.145	0.029	40.67
Treatments	104	3.050 **	4.928 **	305.34**
Parents	13	1.442 **	7.651 **	28.99
Hybrids	90	3.194 **	3.550 **	187.25**
Parent Vs. Hybrids	1	11.004 **	93.523 **	14526.92**
Error	104	0.051	0.043	36.74

* - Significant at 5% level ** - Significant at 1% level

Table 2. Analysis of variance for combining ability for grain yield and quality parameters in maize

Source	**d.f**	**Protein content (%)**	**Starch content (%)**	**Grain yield (q/ha)**
GCA	13	2.17 **	1.65 **	132.21**
SCA	91	1.43 **	2.57 **	155.59**
Error	104	0.02	0.02	18.37
GCA variance		0.13	0.10	7.12
SCA variance		1.40	2.55	137.23
GCA variance/SCA variance		0.09	0.04	0.05

* - Significant at 5% level ** - Significant at 1% level

Table 3. Mean performance of 14 parental lines and 10 best hybrids in maize

Sl. No.	Parents	Protein content (%)	Starch content (%)	Grain yield (q/ha)
1	DMIL 1	9.12	63.34	39.46
2	DMIL 2	9.77	64.22	37.35
3	DMIL 3	9.14	66.21	46.58
4	DMIL 4	9.95	67.11	47.38
5	DMIL 5	8.2	66.21	48.69
6	DMIL 6	8.84	64.51	46.58
7	DMIL 7	9.16	63.80	42.10
8	DMIL 8	8.5	62.34	45.00
9	DMIL 9	10.2	64.23	47.64
10	DMIL 10	10.59	64.33	45.26
11	DMIL 11	10.98	63.80	47.64
12	DMIL 12	10.24	67.03	47.67
13	DMIL 13	10.1	61.44	41.83
14	DMIL 14	10.59	60.60	38.67
		Best hybrids		
1	9 x 5	9.00	65.92	89.6
2	10 x 7	9.49	64.34	86.96
3	4 x 3	10.37	65.78	86.69
4	8 x 7	9.73	65.38	86.50
5	14 x 10	11.59	68.10	86.50
6	11 x 5	8.78	65.87	84.68
7	9 x 8	6.47	63.85	89.60
8	14 x 5	9.52	65.38	84.06
9	9 x 4	11.08	65.29	83.50
10	8 x 4	10.5	65.34	83.26

Table 4. Estimation of general combining ability effects of 14 parents in maize

Sl. No.	Parents	Protein content (%)	Starch content (%)	Grain yield (q/ha)
1	DMIL 1	-0.135 **	-0.351 **	-3.994 ***
2	DMIL 2	-0.287 **	0.048	-0.926
3	DMIL 3	0.268 **	0.477 **	1.119
4	DMIL 4	0.255 **	-0.009	1.68
5	DMIL 5	-0.515 **	-0.328 **	4.566 ***
6	DMIL 6	-0.145 **	0.006	0.344
7	DMIL 7	-0.328 **	-0.491 **	1.944
8	DMIL 8	-0.715 **	-0.06	0.773
9	DMIL 9	0.155 **	0.365 **	5.160 ***
10	DMIL 10	0.269 **	0.410 **	-0.926
11	DMIL 11	0.286 **	-0.04	-3.136 **
12	DMIL 12	0.023	0.465 **	-0.181
13	DMIL 13	0.257 **	-0.246 **	-4.324 ***
14	DMIL 14	0.613 **	-0.247 **	-2.097 *
	SEm±	0.038	0.035	1.031
	CD at 5%	0.076	0.07	2.022
	CD at 1%	0.1	0.092	2.704

* - Significant at 5% level ** - Significant at 1% level

Table 5. Estimates of specific combining ability effects of top 10 hybrids (specific combiners for grain yield in maize)

Sl. No.	Top hybrids	Protein content (%)	Starch content (%)	Grain yield (q/ha)
1	9 x 5	-0.89**	-0.05	14.213**
2	10 x 7	-0.70**	-1.50**	20.358**
3	4 x 3	-0.41**	-0.61**	17.881**
4	8 x 7	0.52**	0	18.402**
5	14 x 10	0.46**	2.01**	22.346**
6	11 x 5	-1.25**	0.31	17.665**
7	9 x 8	-3.23**	-2.38**	12.96**
8	14 x 5	-0.83**	0.04	16.043**
9	9 x 4	0.41**	-1.00**	10.946**
10	8 x 4	0.71**	-0.52**	15.185**

* - Significant at 5% level ** - Significant at 1% level