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COMBINING ABILITY AND GENE ACTION STUDIES FOR YIELD AND QUALITY TRAITS IN BABY CORN (*Zea mays* L.)

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SUMMARY

An investigation was carried out to assess the combining ability and nature of gene action in baby corn genotypes using a diallel mating design (without reciprocal crosses) using 7 homozygous lines namely, FDM 10, FDM 8, FDM 7, FDM 12, FDM 37, FDM 14 and FDM 36. The experiment was set up in a randomized complete block design (RCBD) with 2 replications during *rabi* season of 2010-11. General combining ability studies revealed that FDM 14 was the best combiner for major yield contributing characters including days to tasseling, plant height, number of leaves per plant, number of baby corns per plant, baby corn length, baby corn weight and baby corn yield per plot and FDM 37 was best combiner for yield and quality traits including number of baby corns per plant, baby corn yield per plot, total sugars and reducing sugars. However, the estimates of specific combining ability showed the desirable SCA effects in crosses FDM 37 x FDM 14 and FDM 7 x FDM 14 for all traits studied except for days to tasseling and non-reducing sugars. Gene action analysis revealed preponderance of both additive and non-additive genes for yield and its contributing characters.

Keywords: Genotype x environment interaction, plant breeding, quantitative trait loci, mapping

Short summary statement: In the present investigation, yield and quality attributes of baby corn was governed by both additive and non-additive genes. When the character is under the control of additive gene action, simple selection may be followed to their improvement. If non additive genes are predominant for the traits, heterosis breeding may be effective for their improvement.

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INTRODUCTION

Maize is unique among the cereals on account of its amenability to diverse uses and it has huge potential in the present era of crop diversification. India is emerging as one of the potential baby corn producing countries due to low cost of production and high demand within the country. Baby corn is a young finger like unfertilized cob of maize harvested early within 1-3 days of silk emergence. Baby corn is a good option for crop diversification and it suits to peri-urban agriculture. Further, there is a great potential to earn foreign exchange through export of fresh/canned baby corn and its processed products. Another important feature of baby corn is safe vegetable to eat as it is almost free from residual effects of pesticides as the young cob is rapped with husk and well protected from insect and diseases. Despite manifold uses of baby corn, very little information on breeding strategies followed for improvement in baby corn (Chauhan and Mohan, 2010).

It is a fact that selection of parents on the basis of their mean performance does not necessarily lead to desired results (Rai and Asati, 2011). Therefore, devising a sound breeding strategy to improve the yield of this crop is of paramount importance. Combining ability analysis help breeders in choosing suitable genotypes as parents for hybridization and superior cross combinations through GCA and SCA studies, respectively (Rodrigues and da Silva, 2002; Rai and Asati, 2011). At the same time, it also elucidates the nature and magnitude of different types of gene action involved, which is essential for an effective breeding program. Hence, this investigation was undertaken to study the estimates of general and specific combining ability and gene action in baby corn for yield components and quality characters.

MATERIALS AND METHODS

Experimental material

The present experiment was carried out at Department of Forage Crops, Tamil Nadu Agricultural University, Coimbatore, by involving 7 genetically diverse baby corn inbreds viz., FDM 10, FDM 8, FDM 7, FDM 12, FDM 37, FDM 14 and FDM 36 were used as parents (Table 1) and crossed in diallel mating design following Model-I, Method-II of Griffing (1956). 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 (Singh and Narayanan, 1993)

Experimental methods

The parents and their resulting 21 F_1s were raised in a randomized complete block design (RCBD) with 2 replications during *rabi* season of 2010-11. Each plot consisted of 2 rows of 5 m length and spacing between rows and plants adopted were 30 and 20 cm respectively (3 m^2). One plant per hill was maintained and recommended package of practices was followed to raise a healthy crop (Crop production guide, 2013). Observations on baby corn yield and its component and quality traits including days to 50% tasseling (DFT), plant height (PHT), number of leaves per plant (NOL), number of baby corns per plant (NBC), baby corn length (BCL), baby corn weight (BCW), baby corn yield per plot (BCY), total sugars (TSR), reducing sugars (RSR) and non-reducing sugars (NRS) were recorded on 5 randomly selected plants from each plot.

Mean data was subjected for analysis of general combining ability (GCA), specific combining ability (SCA) and gene action as per method given by Griffing (1956) (method 2 and model I) using the software WINDOSTAT (version 7.1).

Table 1. List of parent material used with study and its origin.

Parents	Origin
FDM 7	Directorate of maize research-winter nursery centre, Hyderabad
FDM 8	Directorate of maize research-winter nursery centre, Hyderabad
FDM 10	Directorate of maize research-winter nursery centre, Hyderabad
FDM 12	Directorate of maize research-winter nursery centre, Hyderabad
FDM 14	Department of forage crops, Coimbatore.
FDM 36	Maize research station, Vagarai
FDM 37	Maize breeding station, Coimbatore

RESULTS AND DISCUSSION

Analysis of variance for GCA and SCA presented in Table 2 revealed that mean sum of squares of combining ability for various yield and yield contributing and quality characters were highly significant for all the characters except baby corn weight, for which SCA effect was found non-significant, showing that the behavior of the best hybrids can be foreseen by using inbreds with high general combining ability. The lack of specific combining ability indicates low genetic complementation among inbreds for alleles which show dominance (Cruz and Regazzi, 1997). This could be explained by assuming that the tested inbreds have the same origin and are obtained from the self-pollination of one indigenous composite-cross of baby corn.

The mean squares of SCA were larger than those of GCA in all the characters except for reducing sugars indicating the preponderance of non-additive gene action in the control of most of the characters. Involvement of non-additive gene action for the characters in present investigation is also in consonance with the findings of Anantha (2004) and Selvarani (2007) for days to tasseling, Geetha and Jayaraman (2000), Anantha (2004) and Prakash and Ganguli (2004) for plant height, Jayakumar and Sundaram (2007) for number of leaves per plant, Rodrigues and da Silva (2002) for baby corn length and Suneetha *et al.* (2000) for non-reducing sugars. On other hand, higher GCA value recorded for reducing sugars than its SCA value indicating involvement of additive genes. This suggested that simple selection would be effective to make desirable improvement of the character under study.

Estimates of general combining ability for various traits have been presented in Table 3. The estimates of GCA effects exhibited that the parent FDM 14 was the best general combiners for most studied characters *i.e.* days to tasseling, plant height, number of leaves per plant, baby corn length, baby corn weight and baby corn yield per plot and parent FDM 37 exhibited desirable GCA effects for plant height, number of baby corns per plant, baby corn yield per plot, total sugars and reducing sugars. So, these parents could be used extensively in hybrid breeding program to increase baby corn yield with quality. Similar to the present investigation were also reported for the following characters *i.e.* plant height (Vacaro *et al.*, 2002; Malik *et al.*, 2004 and Shalim Uddin *et al.*, 2006), number of leaves per plant (Mahajan and Khehra, 1991 and Reddy and Agarwal, 1992), number of baby corns per plant, baby corn length, baby corn weight and baby corn yield per plot (Rodrigues and da Silva, 2002), total sugars and reducing sugars (Selvarani, 2007).

High positive estimates of specific combining ability in absolute values indicates that hybrid performance is relatively superior or inferior to parent lines general combining ability, showing the importance of non-additive interactions resulting from the complementation degree among parent lines in relation to frequency of alleles in loci with some dominance, while low estimates of specific combining ability in absolute value indicates that hybrids behave as expected in relation to general combining ability of parent lines (Vencovsky and Barriga, 1992). In the selection of parent lines used to produce hybrids, the effect of a specific combining ability analyzed in an isolated way has a limiting value. Thus, other parameters should be considered such as the average of hybrids and general combining ability of the respective parent lines (Oliveira *et al.*, 1998). Therefore, superior hybrid combinations, which are important for breeding, are involved with at least one parental line which has the most favorable effects of general combining ability (Cruz and Regazzi, 1997). Thus, it is possible to analyze the 2 hybrids that showed high performance for most of the yield and quality traits, such as FDM 37 x FDM 14 and FDM 7 x FDM 14 (Table 4).

Baby corn yield per plot in the FDM 37 x FDM 14 is associated with high effects of general combining ability of both the parent lines. Therefore, in this case, the high productivity is not due to dominant genetic effects of inbreds but to additive effects. In the FDM 7 x FDM 14 hybrid it is associated with the high effect of the general combining ability of the FDM 14 inbred with one of the highest effects of the estimated specific combining ability, since FDM 7 inbred showed lower general combining ability. In this case, the participation of a specific combining ability is

Table 2. Analysis of variance for combining ability analysis for baby corn yield and quality traits.

Sources	DFT	PHT	NOL	NBC	BCL	BCW	BCY	TSR	RSR	NRS
GCA	11.730**	4196.179**	3.404**	0.235**	4.745**	9.186**	447.7143**	1.020**	1.624**	0.226**
SCA	7.765**	1260.862**	1.135**	0.222**	1.365**	2.784	473.442**	0.167**	0.171**	0.111**
Error	2.055	283.329	0.651	0.033	0.871	2.914	18.277	0.007	0.002	0.011
σ^2 GCA	1.189	450.502	0.342	0.024	0.479	0.859	48.738	0.113	0.180	0.025
σ^2 SCA	6.738	1119.197	0.809	0.204	0.930	1.327	464.304	0.164	0.169	0.105
σ^2 GCA / σ^2 SCA	0.176	0.402	0.423	0.118	0.515	0.647	0.105	0.691	1.065	0.234

*and ** indicates significance at 5% and 1% level respectively.

Table 3. Estimates of mean and general combining ability effects (GCA) of the parents for baby corn yield and quality traits.

Parents	DFT		PHT		NOL		NBC		BCL	
	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
FDM 10	71.00	0.520	90.00	-19.400**	11.34	-0.630**	3.00*	0.180**	7.97	-0.281
FDM 8	72.00	0.470	99.17	-12.090**	11.84	-0.320	2.20	-0.14**	9.22	0.240
FDM 7	70.50	-0.530	111.84	-0.310	12.84	0.350	2.10	-0.050	7.60	-0.738 *
FDM 12	72.50	-0.140	69.84	-14.620**	11.84	-0.210	1.30	-0.250**	8.00	0.140
FDM 37	70.50	-1.860**	127.50	9.810*	10.34	-0.480*	3.20**	0.160**	7.84	-0.810*
FDM 14	76.00**	1.850**	232.34**	43.740**	14.84**	1.160**	2.00	0.100*	11.50**	1.340*
FDM 36	71.50	-0.310	94.00	-7.130	12.67	0.130	3.10*	0.010	8.52	0.100
Mean	72.00		117.81		12.24		2.41		8.66	
SE_d	1.43		16.83		0.80		0.19		0.93	
CD at 5%	2.94		34.50		1.65		0.39		1.91	
$SE_{(gi)}$		0.310		3.670		0.180		0.041		0.201

(Continued)

Parents	BCW		BCY		TSR		RSR		NRS	
	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
FDM 10	6.89	-0.560	132.00**	6.630**	3.21	-0.319*	2.80	-0.219*	0.42	-0.101 *
FDM 8	6.64	-0.280	105.00	-6.750**	3.81	-0 018	3.72**	0.157*	0.09	-0.173*
FDM 7	6.50	-0.937*	96.00	-3.700***	3.90**	0.054*	3.40**	0.035*	0.50	0.020
FDM 12	8.14	0.893*	62.00	-9.480**	3.03	-0.341 *	2.31	-0.647*	0.72*	0.305*
FDM 37	6.22	-0.530	148.00**	8.960**	4.24**	0.468*	3.75**	0.587*	0.49	-0.121 *
FDM 14	11.22*	1.885 *	88.00	4.960**	2.72	-0.259*	2.43	-0.305*	0.29	0.046
FDM 36	6.84	-0.460	138.00**	-0.630	4.41**	0.416*	3.67**	0.392*	0.75*	0.024
Mean	7.49		109.86		3.62		3.15		0.47	
SE_d	1.70		4.27		0.08		0.05		0.10	
CD at 5%	3.49		8.76		0.17		0.10		0.21	
$SE_{(gi)}$		0.371		0.933		0.018		0.010		0.023

Table 4. Estimates of mean and specific combining ability effects (SCA) of the hybrids for baby corn yield and quality traits.

Hybrids	DFT		PHT		NOL		NBC		BCL	
	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
FDM 10 x FDM 8	68.50	-1.520**	138.17	1.890	13.16	0.510*	2.10	-0.300**	7.40	-1.710**
FDM 10 x FDM 7	68.50	-0.520	166.17	18.110**	12.84	-0.490*	2.800*	0.320**	7.80	-0.330
FDM 10 x FDM 12	69.50	0.080	150.17	16.430**	13.34	0.560*	3.100**	0.820**	10.78	1.778**
FDM 10 x FDM 37	66.50	-1.190**	176.67	18.480**	13.50	1.010**	2.16	-0.530**	9.50	1.443**
FDM 10 x FDM 14	71.50*	0.080	193.17	1.050	14.67	0.530*	2.33	-0.310**	10.43	0.220
FDM 10 x FDM 36	70.50	1.250**	163.17	21.930**	13.00	-0.100	2.00	-0.550**	8.80	-0.170
FDM 8 x FDM 7	70.50	1.520**	166.67	11.300*	13.84	0.190	1.90	-0.260**	8.53	-0.120
FDM 8 x FDM 12	70.00	0.630	172.83	31.780**	13.84	0.750**	2.20	0.240**	10.97	1.441**
FDM 8 x FDM 37	68.50	0.860*	180.17	14.670**	13.00	0.190	2.16	-0.210**	7.28	-1.294**
FDM 8 x FDM 14	68.00	-3.360**	207.67	8.240	14.50	0.040	2.900**	0.590**	11.14	0.410
FDM 8 x FDM 36	67.00	-2.190**	169.50	20.950**	14.00	0.580*	1.90	-0.330**	11.60*	2.108**
FDM 7 x FDM 12	65.50	-2.860**	177.83	25.000**	13.67	-0.080	2.16	0.120*	9.15	0.602*
FDM 7 x FDM 37	64.00	-2.630**	195.67	18.390**	14.66	1.190**	2.20	-0.260**	5.97	-1.632**
FDM 7 x FDM 14	69.00	-1.360**	224.50*	13.300*	15.83*	0.710**	2.900**	0.500**	11.34*	1.588**
FDM 7 x FDM 36	69.00	0.800	184.83	24.510**	15.50	1.420**	2.20	-0.120*	8.53	0.030
FDM 12 x FDM 37	62.50	-4.520**	188.33	25.370**	13.84	0.920**	2.00	-0.260**	8.53	0.060
FDM 12 x FDM 14	69.50	-1.250**	208.67	11.780*	15.34	0.770**	2.20	0.00	9.30	-1.325**
FDM 12 x FDM 36	69.00	0.410	173.00	26.980**	13.34	-0.190	2.30	0.180**	9.68	0.300
FDM 37 x FDM 14	70.50	1.470**	236.17**	14.840**	14.66	0.380	3.200**	0.590**	10.25	0.575*
FDM 37 x FDM 36	62.50	-4.360**	198.50	28.040**	14.16	0.920**	2.17	-0.360**	8.66	0.230
FDM 14 x FDM 36	68.50	-2.080**	201.00	-3.380	14.66	-0.230	2.20	-0.270**	9.77	-0.818**
Mean	68.05		184.42		14.06		2.34		9.31	
SE_d	1.43		16.83		0.80		0.19		0.93	
CD at 5%	2.94		34.50		1.65		0.39		1.91	
$SE(_{sij})$		0.910		10.680		0.510		0.06		0.590

*and ** indicates significance at 5% and 1% level respectively

(Continued)

Hybrids	BCW		BCY		TSR		RSR		NRS	
	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
FDM 10 x FDM 8	4.20	-3.063**	99.00	-9.050**	2.82	-0.556**	2.65	-0.561**	0.17	0.000
FDM 10 x FDM 7	5.40	-1.206*	117.000*	5.910**	3.02	-0.428**	2.84	-0.253**	0.19	-0.169**
FDM 10 x FDM 12	10.30	1.863**	141.000**	35.680**	2.94	-0.113**	2.37	-0.037*	0.58	-0.069*
FDM 10 x FDM 37	8.99	1.974**	98.00	-25.760**	4.89**	1.033**	4.68**	1.039**	0.22	0.001
FDM 10 x FDM 14	8.97	-0.460	122.000**	2.240	3.22	0.085**	2.93	0.181**	0.28	-0.101**
FDM 10 x FDM 36	8.16	1.085*	84.01	-30.160**	3.52	-0.290**	3.16	-0.290**	0.36	0.000
FDM 8 x FDM 7	6.68	-0.200	81.00	-16.720**	3.81	0.060*	3.65**	0.185**	0.16	-0.127**
FDM 8 x FDM 12	11.88*	3.160**	101.00	9.060**	3.20	-0.154**	2.63	-0.148**	0.56	-0.010
FDM 8 x FDM 37	6.72	-0.580	100.00	-10.380**	4.26**	0.097**	3.94**	-0.077**	0.32	0.173**
FDM 8 x FDM 14	11.09	1.373**	129.000**	22.620**	3.53	0.099**	3.28	0.151**	0.26	-0.050
FDM 8 x FDM 36	8.50	1.137*	84.60	-16.180**	4.31**	0.199**	4.01**	0.184**	0.31	0.020
FDM 7 x FDM 12	7.97	-0.100	103.00	8.020**	3.76	0.334**	2.28	-0.376**	1.46**	0.699**
FDM 7 x FDM 37	4.85	-1.787**	110.00	-3.430**	3.80	-0.430**	3.74**	-0.150**	0.05	-0.285**
FDM 7 x FDM 14	11.97*	2.916**	126.000**	16.570**	3.62	0.107**	3.36	0.352**	0.26	-0.242**
FDM 7 x FDM 36	6.55	-0.160	103.00	-0.830	4.39**	0.212**	3.82**	0.126**	0.57	0.085**
FDM 12 x FDM 37	8.66	0.200	91.00	-16.650**	3.32	-0.515**	2.95	-0.258**	0.37	-0.255**
FDM 12 x FDM 14	9.36	-1.520**	105.00	1.350	3.74	0.627**	2.06	-0.261**	1.68**	0.888**
FDM 12 x FDM 36	8.45	-0.090	115.00	16.950**	3.61	-0.178**	3.43*	0.418**	0.18	-0.595**
FDM 37 x FDM 14	10.53	1.071*	153.000**	30.910**	4.10**	0.173**	3.82**	0.270**	0.27	-0.091**
FDM 37 x FDM 36	7.89	0.770	98.00	-18.490**	5.06**	0.458**	4.82**	0.569**	0.22	-0.119**
FDM 14 x FDM 36	7.47	-2.063**	99.00	-13.490**	3.74	-0.130**	3.13	-0.225**	0. 61	0.094**
Mean	8.31		107.60		3.75		3.31		0.42	
SE_d	1.70		4.28		0.08		0.05		0.10	
CD at 5%	3.49		8.76		0.17		0.10		0.21	
$SE(_{sij})$		1.080		1.230		0.050		0.030		0.070

*and ** indicates significance at 5% and 1% level respectively

Table 5. Components of genetic variation in a 7 x 7 half-diallel set of baby corn.

Genetic components	DFT	PHT	NOL	NBC	BCL	BCW	BCY	TSR	RSR	NRS
D	2.6131	2722.6880**	1.6922**	0.4710**	1.4194*	1.3038	944.6581**	0.4057**	0.3927**	0.0488
F	-1.1480	1392.5610*	0.4364	0.7855**	-0.5493	-3.2766	1667.6410*	0.0210	-0.2683	0.0074
H_1	23.1845**	2957.4640**	2.4353**	1.0388**	4.3952**	6.4256*	2374.9110**	0.7108*	0.7788*	0.4811
H_2	20.9215**	2664.3960**	2.3381**	0.6490*	4.1912**	6.9855**	1468.1140*	0.6063*	0.5800*	0.3886
h^2	45.3915**	12965.9200**	9.6284**	0.0039	1.0072	1.1260	10.6500	0.0490	0.0745	0.0002
E	1.0536	149.8326	0.3153	0.0271	0.4323	1.7730	8.8181	0.0032	0.0011	0.0052
$(H_1/D)^{1/2}$	2.9787	1.0422	1.1996	1.4851	1.7597	2.2200	1.5856	1.3237	1.4083	3.1400
$H_2/4H_1$	0.2256	0.2252	0.2400	0.1562	0.2384	0.2718	0.1545	0.2133	0.1862	0.2019
KD/KR	0.8626	1.6503	1.2408	3.5607	0.8019	0.2771	3.5115	1.0400	0.6095	1.0496
h^2/H_2	2.1696	4.8664	4.1180	0.0060	0.2403	0.1612	0.0073	0.0808	0.1284	0.0004

*and ** indicates significance at 5% and 1% level respectively

significant for hybrid yield, contributing almost to the general combining ability from both inbreds, regarding the dominance and epistasis effects (Gardner, 1963). However, the hybrid FDM 10 x FDM 12 exhibited high specific combining ability for number of baby corns per plant and baby corn length and FDM 10 x FDM 37 showed highest specific combining ability for total sugars and reducing sugars. About 6 hybrids exhibited higher mean performance and SCA effects for baby corn yield per plot. In respect of baby corn superiority, it is decided by its quality. Hence, the crosses FDM 37 x FDM 14 and FDM 7 x FDM 14 recorded the high mean and SCA effects for yield and quality traits.

The estimates of D, H_1, H_2, F and E parameters along with its components obtained from diallel analysis (Hayman, 1954; Rai and Asati, 2011) are presented in Table 5. Significant value of additive component (D) and non-additive component (H_1 and H_2) observed for plant height, number of leaves per plant, number of baby corns per plant, baby corn length, baby corn yield per plot, total sugars and reducing sugars indicated involvement of both additive and non-additive gene action for the expression of these characters. However, non-additive effects (dominance component) were significantly higher than its additive component (D) for number of leaves per plant, number of baby corns per plant, baby corn weight, baby corn yield per plot, total sugars and reducing sugars. This suggests the preponderance of non-additive (dominance) genetic variation in the expression of these characters. Earlier, preponderance of non-additive gene action in baby corn has also been reported by Rodrigues and da Silva (2002) for baby corn length which is in agreement with our findings.

The mean degree of dominance $(H_1/D)^{1/2}$ was more than unity for all the characters studied which indicated presence of over dominance for expression of these characters. The ratio of $H_2/4H_1$, which was less than 0.25 in all the characters, indicated asymmetrical distribution of positive and negative genes in the parents. The value of KD/KR was higher than the unity for all the characters except days to 50% tasseling, baby corn length, baby corn weight and reducing sugars indicating presence of greater proportion of dominant gene in the expression of these traits. Whereas, for days to tasseling, baby corn length, baby corn weight and reducing sugars KD/KR value recorded less than unity, indicating presence of greater proportion of recessive genes.

In this present study, most of the yield and quality traits includes plant height, number of leaves per plant, number of baby corns per plant, baby corn length, baby corn yield per plot, total sugars and reducing sugars is governed by both additive and non-additive genes but later is predominant suggesting that bidirectional recurrent selection could be adopted for the improvement of these traits, whereas additive gene action was found prominent for the expression of the characters *i.e.* days to tasseling, baby corn weight and non-reducing sugars indicating simple selection could be effective for bringing improvement of this traits in baby corn.

CONCLUSION

FDM 14 and FDM 37 were the best among the 7 parents as it showed desirable mean and GCA effects for most of yield and its contributing traits and yield and quality traits respectively. Therefore these parents could be used extensively in hybrid breeding program with a view to increase baby corn yield with quality. Furthermore, based on mean and SCA effects 2 hybrids FDM 37 x FDM 14 and FDM 7 x FDM 14 were proved to be the best to increase the baby corn yield with better quality. For varietal improvement, these crosses could also be utilized for exploiting promising recombinants and it could be useful towards enhancing baby corn yield and quality.

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