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COMBINING ABILITY FOR YIELD AND ITS COMPONENTS IN WHITE GRAIN QUALITY PROTEIN MAIZE

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ABSTRACT

Combining ability for yield and yield components were carried out in a 8×8 diallel cross of white grain quality protein maize (QPM) to determine the general combining ability (GCA) of the parents and specific combining ability (SCA) of the crosses. Significant mean sum of squares due to GCA and SCA were observed for all the characters studied. Higher magnitude of SCA variance than GCA variance clearly indicated the predominance of non-additive gene action for all the traits. The parental lines P_4, P_7 and Q_6 were found to be the best general combiner for yield components and these parents could be used as donor parents in hybridization to improve traits like days to tasseling, days to silking, plant height, ear height, ear length, ear diameter, grains per ear and 1000 grain weight by accumulation of favorable genes. The significant positive SCA along with high mean yield, the crosses $Q_5 \times P_7$, $P_7 \times Q_6$ and $P_7 \times Q_2$ could be used for commercial variety development, after verifying their performance over locations.

Keywords: Combining ability; QPM; GCA; SCA; gene action

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INTRODUCTION

In the world, maize (*Zea mays* L., 2n=20) ranks third important cereal crop next to wheat and rice in production. The plant is native to Central America, but its suitability to diverse environments, unmatched by any crop, makes it to expand new areas and environment continuously and thus, it explores Asia. The demand of maize increased gradually during nineties with the expansion of poultry industry and this is why, maize yields increased from an average of less than 1 ton per hectare for several decades through 1992 to more than 6 tons per hectare in 2010 by the introduction of hybrid maize varieties. Maize yields per hectare in Bangladesh exceed yields in China and Japan (Bodker, Wulff, and Thorp 2006). The increase in net income from hybrids can be estimated by assuming that farmers replace wheat with maize (Harun-Ar-Rashid et. al., 2012). In world, maize grown with a production 875 million tons (FAO, 2012), while 23 lac tons has been produced in Bangladesh occupies an area of 3.5 lac hectare (Baral, 2016). About 30% of world production is used for direct human consumption and as an industrial input, while 70% is used as animal feed (Pavan, 2009). But in Bangladesh, the sole maize (except popcorn and adulteration in wheat flour) is used up by poultry industries. In this circumstances, white grain QPM maize can play an vital role. However, there was no such variety in Bangladesh and to meet the challenge, Bangladesh Agricultural Research Institute (BARI) introduce some white grain QPM maize inbreds from International Maize and What Improvement Centre (CIMMYT) and eight inbreds were selected.

To determine GCA and SCA information of white grain maize germplasm for identification of nature of genes action involved in the expression of their quantitative traits, genetic diversity evaluation, suitable parental lines selection for hybridization, heterotic pattern classification, heterosis estimation, and hybrids development, the present investigation was undertaken as the above information can be achieved only by combining ability study (Fan et al., 2002; Melani and Carena, 2005; Barata and Carena, 2006; Bello and Olaoye, 2009).

MATERIALS AND METHODS

Eight white grain QPM inbred lines (P_2, P_4, P_6, Q_3, Q_5, P_7, Q_6 and Q_2 as parent 1, parent 2 parent 3 parent 4 parent 5 parent 7 and parent 8, respectively) selected based on phenotypic characters were mated in a 8×8 diallel fashion without reciprocals during rabi season in 2013-2014 and their performance (28 F_1's and their parents) were examined with four checks (BARI hybrid maize 5, BARI hybrid maize 7, BARI hybrid maize 9 and 900M) in a Alpha Lattice Design with two replications at the experimental field of BARI, Gazipur in the following rabi season 2014-2015. Notably, P and Q series inbreds were extracted from two different populations. Each and every entry was sown in a single row of 4 m long plot and by proper thinning one plant per hill was retained. The spacing between rows was 60 cm and between plants was 20 cm.

The data of plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of grains per ear, 1000 grain weight (g) and yield/plant from each plot were recorded on the basis of ten randomly selected plants, while that of days to tasseling, silking and root lodging were taken on whole plot basis. Analysis of variance was carried out for all the above traits, whereas GCA and SCA were calculated following Griffing (1956) Method 2, Model II.

RESULTS AND DISCUSSION

The mean performance of 28 crosses for yield related traits along with three checks is presented in Table 1. The presence of considerable genetic variability was obvious among traits as genotypes differed significantly. Four hybrids showed at per yield with commercial check 900M, while the cross $P_7 \times Q_2$ had significantly higher yield. Highly significant mean squares for GCA and SCA for all the characters clearly indicate that those traits were controlled by both types of gene actions additive and non-additive (Table 2). The results agreed with the findings of Amiruzzaman *et al*. (2011) and Verma and Narayan (2008) in QPM maize.

Although both additive and non-additive genetic variances are important for the traits, the higher magnitude of SCA than GCA for grain yield indicates the importance of non-additive gene action (dominance and epistasis) in its inheritance. The result is in close agreement with Bhatnagar *et al*. (2004), Hossain and Prasanna (2008) and Amiruzzaman *et al.* (2011) who reported the importance of both additive and non-additive genetic variances with higher magnitude of SCA over GCA for yield-related characters of QPM in their study.

Table 1. Mean performance of QPM hybrids obtained from 8 × 8 half diallel cross along with checks

Sl. No.	Crosses/ Checks	Days to tassel	Days to silk	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter(cm)	Grains / ear (no.)	1000 grain wt. (g)	Yield/ plant (g)	Root lodging (1-5)
1	$P_2 \times P_4$	86	92	179	78	15	4	406	360	125.4	1
2	$P_2 \times P_6$	94	99	190	99	14	4	349	360	126.4	1
3	$P_2 \times Q_3$	87	93	180	82	15	4	329	360	105.6	1
4	$P_2 \times Q_5$	92	98	198	95	16	4	448	380	141.3	2
5	$P_2 \times P_7$	91	96	185	90	15	5	448	390	137.4	2
6	$P_2 \times Q_6$	92	97	199	103	18	4	453	370	150.1	3
7	$P_2 \times Q_2$	89	94	191	91	16	4	448	380	116.4	2
8	$P_4 \times P_6$	94	99	195	108	15	5	375	390	132.7	2
9	$P_4 \times Q_3$	86	92	181	92	17	4	434	395	136.5	3
10	$P_4 \times Q_5$	89	94	202	104	18	5	497	355	198.0	2
11	$P_4 \times P_7$	89	94	182	93	17	5	491	360	177.6	2
12	$P_4 \times Q_6$	90	95	201	109	17	4	483	360	184.6	2
13	$P_4 \times Q_2$	87	93	177	93	16	4	364	405	139.8	3
14	$P_6 \times Q_3$	92	97	189	104	16	4	405	390	129.4	2
15	$P_6 \times Q_5$	98	103	212	124	16	4	401	340	122.1	2
16	$P_6 \times P_7$	94	99	196	111	16	4	448	430	153.4	2
17	$P_6 \times Q_6$	94	98	190	107	17	4	470	380	141.0	3
18	$P_6 \times Q_2$	93	97	192	102	16	4	378	340	164.4	4
19	$Q_3 \times Q_5$	93	98	203	111	17	4	448	380	158.7	4
20	$Q_3 \times P_7$	87	92	190	98	17	5	453	370	157.6	4
21	$Q_3 \times Q_6$	88	93	196	101	18	4	490	370	167.1	5
22	$Q_3 \times Q_2$	91	96	190	98	15	4	456	340	121.3	2
23	$Q_5 \times P_7$	90	94	206	110	18	5	479	395	212.7	2
24	$Q_5 \times Q_6$	100	105	173	97	14	4	338	330	93.5	5
25	$Q_5 \times Q_2$	90	94	191	98	16	4	409	335	115.2	2
26	$P_7 \times Q_6$	87	92	190	100	18	5	496	410	206.8	3
27	$P_7 \times Q_2$	84	89	185	91	17	5	464	420	218.0	1
28	$Q_6 \times Q_2$	87	92	190	89	18	4	490	390	173.5	1
29	BHM-5	89	94	193	106	17	4.4	406	350	128.5	5
30	BHM-7	85	90	197	108	17	4.8	452	365	146.2	4
31	900M	87	92	186	100	17.6	4.8	495	410	203.8	5
32	BHM-9	87	92	192	94	19	4.1	470	380	166.8	4
	F-test	**	**	**	**	**	**	**	**	**	
	CV(%)	0.40	0.41	3.57	3.34	3.09	4.42	4.88	5.84	1.76	
	CD(5%)	0.74	0.81	13.03	6.17	0.97	0.38	38.50	45.03	4.63	

Scale (1-5): 1-resistant and 5-susceptible; ** Significant at 1% level.

Table 2. Analysis of variances for combining ability of yield and yield components in QPM

Source	df	Days to tassel	Days to silk	Plant height	Ear height	Ear length	Ear diameter	Grains/ ear	1000 grain Wt.	Yield/ plant
GCA	7	25.5**	22.1**	361.2**	354.3**	6.5**	0.2**	5077**	796**	1396**
SCA	28	24.8**	22.7**	465.8**	262.1**	3.4**	0.1**	9475**	5720**	2372**
Error	35	0.07	0.08	21.0	4.7	0.1	0.02	183.4	390.8	2.6
σ^2GCA/σ^2SCA		0.003	0.003	0.02	0.03	0.09	0.14	0.04	0.09	0.04
σ^2_A		0.13	0.12	20.92	18.42	0.63	0.03	879.61	984.83	195
σ^2_D		24.78	22.66	444.83	257.47	3.28	0.11	9291.42	5329.59	2369

** Significant at 1% level.

General Combining Ability (GCA) Effects

The GCA effects of parents were calculated and have been presented in Table 3. based on their effects parents were grouped as good, average and poor general combiners. Parents having desirable and significant GCA effect were considered as good general combiners, whereas average parents as average combiners. Parents possessed significant but negative or undesirable GCA effects were designated as poor or low combiners.

Table 3. General combining ability (GCA) effects and mean performance (in parenthesis) of parents for yield and yield related characters in QPM

Sl. No.	Parents	Days to tassel	Days to silk	Plant height	Ear height	Ear length	Ear diameter	Grains/ ear	1000 grain Wt.	Yield/ plant
1	P_2	0.1	0.4**	-7.6**	-8.7**	-0.8**	-0.1	-16.8**	-5.4	-14.2**
		(101)	(105)	(120)	(52)	(12)	(3.8)	(240)	(225)	(67.5)
2	P_4	-1.3**	-1.1**	-6.5**	-4.5**	0.1	0.2**	-4.0		4.4**
		(99)	(103)	(127)	(54)	(13)	(4.5	(220)	3.1 (260)	(64.5)
3	P_6	2.7**	2.5**	4.2**	6.7**	-0.9**	-0.1	-40.3**	-1.4	-11.1**
		(100)	(104)	(157)	(70)	(10)	(3.8)	(160)	(240)	(49.5)
4	Q_3	-1.6**	-1.5**	-1.1	-2.8**	0.2	-0.1	10.3*	-1.4	-5.6**
		(96)	(100)	(149)	(57)	(14)	(4.1)	(299)	(242)	(73.5)
5	Q_5	1.8**	1.6**	10.8**	8.8**	0.1	-0.1		-10.4	-0.3
		(99)	(104)	(180)	(89)	(14)	(3.8)	0.3 (256)	(240)	(67.5)
6	P_7	-1.0**	-1.0**	-0.5		1.5**	0.3**	32.7**	18.6**	22.2**
		(100)	(105	(149)	1.1 (74)	(18)	(4.4)	(289)	(272)	(69.0)
7	Q_6	0.3**	0.2**	3.1*	2.9**	0.6**	-0.1	21.0**		9.3**
		(99)	(103)	(164)	(76)	(14)	(4.1)	(260)	3.6 (260)	(78.0)
8	Q_2	-1.1**	-1.1**	-2.6	-3.4**	-0.7**	-0.3**	-3.1	-6.9	-4.7**
		(99)	(104)	(148)	(66)	(10)	(2.6)	(245)	(250)	(42.0)
	$SE_{(gi)}$	0.08	0.08	1.36	0.64	0.10	0.04	4.01	5.85	0.48
	$LSD_{(5\%)}$	0.18	0.19	3.20	1.51	0.22	0.09	9.47	13.82	1.12

* and ** Significant at 5% and 1% level. Values in parenthesis are mean of the traits.

To develop early and short stature hybrid(s), which would not be laid down by strong wind, hail and/or storm, then negative significant GCA effects for days to tasseling, silking, plant height and ear height are to be considered. From the Table 3, it was observed that parents P_4, P_7, Q_2 and Q_3 for both days to tassel and silk, P_2 and P_4 for plant height and ear height exhibited significant negative GCA effects. The good general combiners for major yield determining characters were P_7 and Q_6 (longer ears); P_4 and P_7 (thick ears); P_7, Q_3 and Q_6 (higher number of kernels per ear) and P_7 (bold kernels). Positive estimates for these traits are desirable since these traits directly contribute to yield in maize.

Parents P_4, P_7 and Q_6 were good combiner of yield and some important yield contributing traits (Table 3). These parents could be used in breeding program for obtaining higher yield and some of the desirable traits. Parent P_7 was the best general combiner for yield. It had significant positive GCA value for all yield components along with high mean indicated the parent could be very useful for combining more positive alleles. The result is confirmed by the findings of Amiruzzamam *et al.* (2010), Ivy and hawlader (2000) and Hussain *et al.* (2003). Finally, it can suggest that P_7 was an excellent combiner of yield and yield contributing traits and could be used extensively in hybrid breeding program with a view to increase yield.

Specific Combining Ability (SCA) Effects

The SCA effects of the crosses for all the characters studied are presented in Table 4. The desirable significant negative SCA effect was obtained from 22 crosses for both days to tasseling and silking. Cross $Q_5 \times Q_6$ had significant but negative SCA effect for both plant and ear height, while $Q_6 \times Q_2$ showed for only ear height. Significant positive SCA effects were desirable for ear length, ear diameter, number of grains per ear and

1000-grain weight and different numbers of cross combinations were identified as the best combinations for those characters (Table 4).

Among the crosses, twenty three had significant positive SCA effects for yield per plant and in most of the cases, one or both parents were good combiners, which indicates the vital role of parental lines' GCA. Xingming *et al.* (2002) also reported similar result. The crosses with high SCA value also had high *per se* performance (Table 1). Vasal (1998) revealed that enrollment of at least one good combiner in crossing program prioritize higher heterosis in maize which confirmed the findings of the present study. To obtain heterosis for a complex trait like yield, a superior parent for one component should be crossed with a parent superior for another. Vasal (1998) also suggested that both combining ability and *per se* performance are important and thus balanced resources must be spent on each of these two aspects. The highest value of SCA effects for yield was observed in $P_7 \times Q_2$ (69.4) followed by $P_4 \times Q_5$ (62.8) and $Q_5 \times P_7$ (59.7). The crosses involved high × high, average × average, low × low, high × average or high × low general combining parents yielded in desirable significant SCA effects for different characters, manifested attribution of sizeable additive × additive gene action of good combiner parents.

Table 4. Specific combining ability (SCA) effects for yield and yield related characters in 8 × 8 diallel cross of QPM hybrids

Crosses	Days to tassel	Days to silk	Plant height	Ear height	Ear length	Ear diameter	Grains/ ear	1000 grain Wt.	Yield/ plant
$P_2 \times P_4$	-5.2**	-4.5**	11.3**	-1.2	0.1	0.1	34.7**	24.1**	4.1**
$P_2 \times P_6$	-1.2**	-1.2**	11.5**	8.5**	0.6**	-0.1	-5.9	28.6**	20.7**
$P_2 \times Q_3$	-3.8**	-3.1**	6.4**	1.5	-0.4**	-0.3**	-36.6**	28.6**	-5.6**
$P_2 \times Q_5$	-2.3**	-1.8**	12.4**	2.9**	0.6**	0.2**	72.4**	57.6**	24.7**
$P_2 \times P_7$	-0.5**	-0.6**	10.7**	5.1**	-1.1**	0.2*	39.9**	38.6**	-1.7*
$P_2 \times Q_6$	-1.3**	-1.5**	21.6**	16.3**	2.3**	0.3**	56.7**	33.6**	23.9**
$P_2 \times Q_2$	-2.3**	-2.5**	19.3**	11.1**	1.9**	0.3**	75.7**	54.1**	4.2**
$P_4 \times P_6$	0.2*	0.4**	15.5**	13.8**	0.1	0.2**	27.2**	50.1**	8.4**
$P_4 \times Q_3$	-3.9**	-3.0**	6.3**	6.9**	1.5**	-0.1	35.5**	55.1**	6.6**
$P_4 \times Q_5$	-3.9**	-3.7**	15.9**	7.2**	2.6**	0.2**	108.6**	29.1**	62.8**
$P_4 \times P_7$	-1.0**	-1.1**	7.2**	3.9**	0.3	-0.2**	70.1**	0.1	19.9**
$P_4 \times Q_6$	-1.9**	-1.8**	22.6**	18.6**	0.3*	-0.1**	73.3**	15.1	39.9**
$P_4 \times Q_2$	-2.9**	-2.4**	3.8*	8.4**	0.7**	0.1	-21.1**	55.6**	9.0**
$P_6 \times Q_3$	-1.4**	-1.2**	3.6	7.6**	1.4**	0.2**	42.9**	54.5**	15.1**
$P_6 \times Q_5$	1.1**	1.1**	15.1**	16.5**	0.8**	-0.1	48.9**	13.6	2.4**
$P_6 \times P_7$	-0.1	0.2*	10.4**	11.2**	0.1	-0.1*	63.5**	74.6**	11.3**
$P_6 \times Q_6$	-1.4**	-2.0**	0.8	5.4**	1.7**	0.1*	97.2**	39.6**	11.7**
$P_6 \times Q_2$	-1.4**	-1.6**	8.5**	6.7**	1.6**	0.4**	29.2**	-9.9	49.1**
$Q_3 \times Q_5$	-0.1	0.2	10.9**	13.1**	0.6**	0.1**	45.3**	53.6**	33.6**
$Q_3 \times P_7$	-3.2**	-3.2**	9.8**	7.7**	-0.1	0.1	17.3**	14.6	10.0**
$Q_3 \times Q_6$	-3.0**	-2.9**	11.7**	8.4**	1.2**	-0.2**	66.5**	29.6**	32.3**
$Q_3 \times Q_2$	1.5**	1.5**	11.4**	12.2**	-0.4**	0.2**	56.6**	10.1	0.6
$Q_5 \times P_7$	-3.7**	-4.4**	13.8**	7.6**	1.0**	0.4**	53.9**	48.5**	59.7**
$Q_5 \times Q_6$	4.9**	5.4**	-22.8*	-6.7**	-2.8**	-0.5**	-75.4*	-1.4	-46.6**
$Q_5 \times Q_2$	-3.0**	-3.7**	0.4	0.6	0.9**	0.2**	19.6**	14.1	-10.8**
$P_7 \times Q_6$	-4.7**	-4.5**	5.5**	3.5**	0.4**	0.3**	50.1**	59.6**	44.3**
$P_7 \times Q_2$	-6.2**	-6.1**	6.2**	1.3	0.3*	0.5**	42.2**	30.1**	69.4**
$Q_6 \times Q_2$	-4.5**	-4.3**	7.6**	-3.0**	2.4**	0.4**	79.9**	55.1**	37.8**
SE(ij)	0.33	0.36	5.79	2.74	0.40	0.18	17.13	25.00	2.06
$LSD_{(5\%)}$	0.67	0.73	11.87	5.62	0.82	0.37	35.08	51.21	4.22

* Significant at 5 percent level; ** Significant at 1 percent level

Among the higher three SCA effects $P_7 \times Q_2$ belonged to high × low combination, manifesting complementary gene action as well as additive effect of the high parent, while $P_4 \times Q_5$ and $Q_5 \times P_7$ belonged to high × average combinations. The low × low cross combinations with appreciable SCA effects might be ascribed as non-allelic gene action of dominance × dominance type which produced over dominance. So, the superior performance of most hybrids might be the result of
epistatic interaction and the GCA effects of their parents were not reflected in SCA. This result is in accordance with the findings of Ivy and Howlader (2000). Moreover, Amiruzzaman *et al*. (2011) also pointed out that the SCA is a result of the interaction of GCA effects of the parents and that it can improve or deteriorate the hybrid expression compared to the expected effect based on GCA only.

Considering the mean performance and significant desirable SCA effects three crosses $Q_5 \times P_7$, $P_7 \times Q_6$ and $P_7 \times Q_2$ could be used for commercial variety development after verifying their performance over locations, and parents P_4, P_7 and Q_6 could be utilized in different breeding program.

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