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COMBINING ABILITY ASSESSMENT OF POPCORN CONSIDERING YIELD AND KERNEL POPPING QUALITY

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Abstract

A line × tester experiment was conducted at early generation of popcorn involving eight superior female lines and three testers for grain yield, its components as well as popping quality to determine the effect of combining ability both General combining ability (GCA) and specific combining ability (SCA). Highly significant genotypic differences were observed indicated wide range of variability present among the genotypes. The inbred parents Thai Pop / S_3-28 and Thai Pop / S_3-20 were identified as the best general combiners due to their good combining ability effect for grain yield and popping quality and also their ability to transmit characters to their progenies for most of the characters. The crosses with high SCA effect for grain yield evolved from high × low general combiner parents were reveled additive × dominance type of gene action. The good combination crosses were Thai Pop /S_3-1 × PCB /S_6-13, Thai Pop /S_3-17 × PCB /S_6-39 and Thai Pop /S_3-20 × PCB /S_6-39 could be used in future breeding program to develop high yielding popcorn hybrids with desirable poped kernel qualities. The information on the nature of gene action with respective variety and characters might be used depending on the breeding objectives.

Keywords: Popcorn, maize, GCA, SCA, line × tester, popping quality.

Introduction

Popcorn broadly belongs to maize, *Zea mays* L. or corn which is the most plentifully grown cereal in the world. Corn can be categorized into major types namely, Dent, Flint, Pod, flour and sweet corn. Popcorn is a special kind of flint corn that was particularly nominated by Indians in early Western civilizations time.

The difference of popcorn from other flint and dent corns represents firstly by the hard starch type and secondly by very hard pericarp and outer layers of endosperm, which permit the internal pressure and temperature to rise high enough to pop (Cretors, 2001).

Repeated buying of a particular popcorn brand depends greatly much on its taste and quality. Expansion volume and the number of unpopped corn grains are the most critical factors determining the popcorn quality (Song *et al.*, 1991). The expansion volume is a very important quality criterion commercially, because

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commercial popcorn buyers buy by weight and sell the popped corn by volume (Ceylan and Karababa, 2002).

Results from classical quantitative genetics and traditional statistical analysis have shown that popping characteristics are quantitatively inherited, controlled by multiple genes (Clary 1954; Ziegler 2001), influenced by environmental effects (Li *et al.* 2003) and popping methods (Dofing *et al*. 1990).

Hence, hybrid development program was undertaken to exploit maximum heterotic effects for yield and quality of popcorn, where parental selection plays the key role in hybrid development. In this context, Line × Tester analysis by Kempthome (1957) has widely been used for evaluation of inbred lines by crossing them with testers. The value of any inbred line in hybrid breeding ultimately depends on its ability to combine very well with other lines to produce superior hybrids. The present study involving a Line × Tester analysis aimed at to determine both the general combining ability (GCA) and specific combining ability (SCA) of crosses of the popcorn inbred lines for grain yield, yield contributing characters and kernel popping quality and to explore heterotic hybrid combinations. Additionally, this experimemntal approach evaluated the cross performance for yield and popping related traits.

Materials and Methods

The experimental materials comprised of eight selected S_3 generation lines of Thai pop corn (as female parents) and three testers (PCB/S6-11, PCB/S6-13, PCB/S6-39) of popcorn. Total 24 crosses combinations were made through Line × Tester mating design during 2013-14. The 24 F1's along with two checks (NI5820 and Khoibhutta) were sown following Alpha lattice design with two replications at the research field of Bangladesh Agricultural Research Institute, Joydebpur during rabi, 2014-15. Spacing was maintained at 60 cm × 20 cm. Two border rows were used at each end of the replication to minimize the border effect. Fertilizers was applied @ 250, 55, 110, 40, 5 and 1.5 Kg/ha of N, P, K, S, Zn and B, respectively. All the recommended packages of practice were followed and the observations were recorded on ten randomly selected plants for quantitative characters viz. days to 50% tasselling, days to 50% pollen shading, days to 50% silking, plant and ear height, ear length, ear diameter, number of grains per ear, 1000-grain weight, and grain yield. Yield maturity traits were recorded from plot basis and yield was converted to ton/ha. After harvesting and proper drying, the popcorns were tested for quality by popping. Qualitative characters like popping % and popping expansion was recorded. After popping the popped kernels were tasted by 17 evaluators (Scientists and staffs) for scoring the taste of quality following 1-5 scale. During scoring the best one was scored 1 and the worst one 5. All these observations were considered in combining ability analysis (excluding parents) following Sharma (1988) using statistical analysis package ‘R 4.2’.

Results and Discussion

The analysis of variance revealed significant differences among the parents, crosses and parent vs. crosses for popping quality and most of the the traits studied, indicating sufficient genetic variability present among them. The analysis of variance also revealed significant differences in the variance due to testers, and Line x Testers in some of the yield and quality traits (Table 1). Similar difference for grain yield and other characters were reported by Sofi and Rathor (2006). No significant differences were observed among the lines but significant difference was observed for the testers regarding tasseling, pollen shedding, silking, plant height and ear height. Significant differences were also existed in the interactions of Line × Testers for yield, yield related traits and popping quality traits, indicating that there were wide range of variability among lines and testers for the traits.

The higher estimate of dominance variance as compared to additive variance for all of the characters was probably due to predominance of non-additive gene action, which suggest the scope of improvement of these characters through heterosis breeding. Similar non-additive gene action was also found by Singh and Singh (1998) and they reported that non-additive gene action for plant height, ear length, kernel rows, 1000- grain weight. Mahto and Ganguly (2001) observed non additive gene action for grain yield. Both additive and dominant genetic effects play very important roles in the inheritance of popping characteristics as reported by Dofing *et al.,* (1991). The contribution of lines, testers and their interactions to total variances are presented in Table 2. The proportional contribution of lines and interactions to total variances was much higher than testers in all the traits except days to tassel, days to pollen shading, days to silking, plant height and ear height. However, the contribution of lines was higher than the interactions to total variances only for test quality and was nearly equal in case of popping expansion. In this study interaction contributed maximum to total variance for quality traits and grain yield which was followed by female lines. Testers contributed lowest to total variance for yield and quality, which is in conformity with Amiruzzaman (2010) and Li *et.al.* (2003).

General combining ability (GCA) effects

The gca effects showed that line Thai Pop/S_{3}-1exhibited significant negative gca effects for pollen shedding and could be utilized for evolving earliness (Table 3). Hussain *et al*. (2003) also observed similar phenomenon in their study. For plant height, line Thai Pop /S_{3}-28 exhibited significant negative effects which could be used for developing shorter plant. Ahmed *et al.* 2017 and Ahmed *et al.* 2017 also

Table 1. Analysis of variance for grain yield, its components and popping quality traits in line x tester analysis of pop corn

Source of variation	df	DT	DPS	DS	PH	EH	EL	ED	NK/R	TSW	Yi (t/ ha)	POP%	PE	TQ
Genotypes	34	30.99**	29.23**	31.82**	1545.2**	492.6**	12.09*	2.21**	99.49**	1280.74**	54.36**	479.83**	85.35**	0.29**
Parents	10	33.136**	28.40**	24.83**	692.43**	185.63*	25.11**	3.58**	56.88**	1673.6**	130.30**	893.04**	97.36**	0.368**
Parents vs. Crosses	1	452.58**	432.46**	476.36**	36321.6**	9323.15**	70.08**	2.79	2322.9**	5234.1**	155.92**	1201.4**	151.55**	0.697*
Crosses	23	11.74**	12.07**	15.54**	403.96**	242.13**	3.91	1.59*	21.35*	938.02**	16.94	340.66**	79.34**	0.257*
Lines	7	1.76	2.93	3.43	145.10	96.61	2.46	1.74	22.95	840.40	20.86	257.08	112.29	0.443
Testers	2	108.52**	96.58**	132.94**	2751.44**	1527.65**	0.90	1.90	13.56	19.27	17.45	211.57	110.30	0.061
Lines ×Testers	14	2.89	4.56	4.82	198.03*	131.24*	5.06	1.47	21.66*	1118.08**	14.91	400.90**	58.44**	0.192
Error	34	3.43	3.05	2.98	77.54	60.03	6.35	0.85	10.54	282.63	15.75	0.97	0.34	0.106
Estimates of components of variance														
σ^2gca		5.283	5.915	5.975	17.784	3.457	0.215	0.097	0.869	27.360	0.039	5.512	0.350	0.005
σ^2sca		-410.98	-460.23	-465.06	-1283.78	-238.82	-16.04	-7.47	-61.33	-2085.75	-1.01	-389.11	-22.39	-0.37
σ^2gca /σ^2sca		-0.013	-0.013	-0.013	-0.014	-0.014	-0.013	-0.013	-0.014	-0.013	-0.039	-0.014	-0.016	-0.013

*, ** indicate significant at 5% and 1% respectively;

DT= Days to 50% tasseling, DPS= Days to 50% pollen shedding, DS= Days to 50% silking, PH= Plant height, EH= Ear height, EL= Ear length, ED= Ear diameter, NK/R=Kernel number per row, TSW= Thousand grain wt., Yi= Yield (t/ha), Pop%= Popping percentage, PE= Popping expansion; TQ=Taste of Quality scale (1= very good, 5 = very poor).

Table 2. Proportional contribution of lines, testers and their interactions to total variance of pop corn

Source	DT	DPS	DS	PH	EH	EL	ED	NK/R	TSW	Yi (t/ ha)	POP%	PE	TQ
Due to line	4.56	7.38	6.71	10.93	12.14	19.184	33.30	32.72	27.27	37.48	22.97	43.08	52.51
Due to tester	80.41	69.61	74.41	59.23	54.86	1.993	10.39	5.52	0.18	8.96	5.40	12.09	2.06
Due to L×T	15.01	23.00	18.88	29.84	32.99	78.823	56.31	61.75	72.55	53.57	71.63	44.83	45.43

Table 3. GCA effects of parents for different yield contributing traits of pop corn

Tester/Tester	DT	DPS	DS	PH	EH	EL	ED	NK/R	TSW	Yi (t/ ha)	POP%	PE	TQ
Testers													
1. PCB/S_6-11	-3.00**	-2.83**	-3.31**	14.56**	11.02**	-0.167	0.36	1.00	-0.104	-0.88	3.86**	1.66**	0.022
2. PCB/S_6-13	1.69**	1.54**	1.94**	-10.88**	-7.60**	-0.104	-0.02	-0.188	1.146	1.16	-3.35**	-3.02**	0.048
3. PCB/S_6-39	1.31**	1.29**	1.38**	-3.69	-3.417	0.271	-0.33	-0.812	-1.042	-0.28	-0.51*	1.36**	-0.07
SE (gi)	0.463	0.437	0.431	2.201	1.937	0.63	0.231	0.812	4.203	0.992	0.24	0.14	0.081
Lines													
1. Thai Pop/S_3-1	-1.25	-1.479*	-1.229	1.75	4.292	-0.458	-0.69	1.0	-16.35*	-1.31	-3.13**	4.92**	0.014
2. Thai Pop/S_3-8	0.083	0.521	0.438	6.417	4.792	0.375	0.81*	1.5	11.98	-0.896	-3.30**	2.97**	-0.011
3. Thai Pop/S_3-16	0.417	-0.146	-0.562	0.083	3.958	0.208	0.81*	-0.5	-9.69	-0.70	0.36	2.13**	0.38**
4. Thai Pop/S_3-17	-0.083	0.188	-0.396	2.417	-1.042	0.042	-0.19	0.167	-6.35	-0.35	-5.30**	0.58*	0.07
5. Thai Pop/S_3-20	-0.083	-0.479	-0.396	4.25	0.125	0.042	-0.19	-1.167	2.81	-0.36	7.69**	3.00**	-0.22
6. Thai Pop/S_3-26	0.250	0.521	0.438	-0.75	-2.375	0.875	-0.19	2.333	8.65	-0.12	7.78**	-2.83**	-0.43**
7. Thai Pop/S_3-28	0.250	0.521	0.938	-7.417*	-5.708	0.208	-0.02	0.667	-8.02	4.52**	5.78**	-2.41**	-0.08
8. Thai Pop/S_3-29	0.417	0.354	0.771	-6.75	-4.042	-1.29	-0.35	-4.0**	16.98*	-0.79	-9.88**	-8.37**	0.35**
SE (gj)	0.756	0.713	0.705	3.595	3.163	1.029	0.38	1.325	6.86	1.62	0.402	0.238	0.132

*, ** indicate significant at 5% and 1% respectively;

DT= Days to 50% tasseling, DPS= Days to 50% pollen shedding, DS= Days to 50% silking, PH=Plant height, EH= Ear height, EL= Ear length, ED= Ear diameter, NK/R=Kernel number per row, TSW= Thousand grain wt., Yi= Yield (t/ha), Pop%= Popping percentage, PE= Popping expansion; TQ =Taste of Quality scale (1 = very good, 5 = very poor).

found similar result in their study. popping expansion. Better taste was scored for the lines Thai Pop/S_{3-}16 and Thai Pop/S_{3-}29. The tester PCB/S_6-11showed significant positive GCA effects for quality parameter but negative gca for yield. As gca is generally associated with additive gene action in inheritance of characters, the lines and testers with high gca may be utilized in hybridization programme to improve a particular trait through transgressive segregation. According to Jenkins (1935) and Sprague (1946a), the early generation determination of lines combining ability does not change significantly with continued inbreeding at later generations.

Only one line Thai Pop/S_{3-}29 had significant positive gca effect for 1000 - grain weight that could be utilized for evolving bold grained corn. The line Thai Pop /S_{3-}28 exhibited highly significant positive gca effects for yield which also had negative significant effect for plant height. Since, it could be used for developing high yielding dwarf hybrid. Significant gca effect for yield in maize was also reported by Paul and Duara (1991). In case of qualitative characters, the line Thai Pop /S_{3-}16 only showed positive effect for all the three quality parameters where, popping expansion and taste quality were highly significant. On the other hand, the lines Thai Pop/S_{3-}20, Thai Pop/S_{3-}26 and Thai Pop/S_{3-}28 had positive significant GCA effect for popping % and Thai Pop/S_{3-} 1, Thai Pop/S_{3-}8, Thai Pop/S_{3-}17 and Thai Pop/S_{3-}20 posses significant effect for

Specific combining ability (SCA) effects

Developing high-yielding hybrids depend on careful choice of parents. Information regarding general and SCA is very important to select desirable parents and crosses.

The Specific combining ability effects and mean of the crosses for grain yield, its components and other qualitative characters are presented in Table 4. Positive sca effect is expected for yield components. Significant positive sca was observed for yield in Thai Pop/S_3-28 × PCB/S_6-13 with higher mean yield, which also exhibited positive significant sca effect for popping% having higher mean value and positive but non-significant sca regarding popping expansion and 1000 grain weight. The genotype Thai Pop/S_3-29 × PCB/S_6-11 possess non-significant but positive sca yield and all its component traits along with all popping parameters except test quality. Considering popping quality, the hybrids; Thai Pop/S_3-8 × PCB/S_6-11, Thai Pop/S_3-17 × PCB/S_6-11, Thai Pop/S_3-1 × PCB/S_6-13, and Thai Pop/S_3-29 × PCB/S_6-13 were credited for having significant positive sca for all the popping traits except test quality where, it showed only non-significant but positive sca against effect. Only the genotype Thai Pop/S_3-26 × PCB/S_6-11 exhibited significant positive sca for test quality but its other traits were not favorable. Considering all the characters under study, the genotype Thai Pop/S_3-17 × PCB/S_6-39 exhibited favorable performances like, negative significant sca for days to

Table 4. SCA effects and mean performance of the F_1 hybrids for grain yield, yield contributing traits and different popping quality of popcorn

Crosses	DT		DPS		DS		PH		EH		EL		ED	
	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean
1. Thai Pop/S_3-1 × PCB/S_6-11	-0.5	77.5	-1.333	81.5	-1.521	81.5	-5.062	171.5	-5.854	79.5	-2.17	14.5	-0.19	11
2. Thai Pop/S_3-8 × PCB/S_6-11	0.667	82	0.667	86.5	0.812	87.5	-3.229	161	-7.854	71	0.5	17.7	1.312*	10.7
3. Thai Pop/S_3-16 × PCB/S_6-11	-0.167	83.5	-0.667	89	-0.688	90	2.104	153.5	6.479	72.5	-1.33	18.5	-0.69	11
4. Thai Pop/S_3-17 × PCB/S_6-11	0.333	80	1	85.5	1.146	85.5	10.77	178	7.979	78	-0.67	18	-0.69	14
5. Thai Pop/S_3-20 × PCB/S_6-11	-1.167	83	-1.333	88.5	-1.354	89.5	-7.062	164	-6.688	72.5	0.333	16.8	-0.19	12.2
6. Thai Pop/S_3-26 × PCB/S_6-11	0.5	84	0.167	89	0.312	89	-3.562	158	-6.688	74	0	18	-0.69	11
7. Thai Pop/S_3-28 × PCB/S_6-11	0.5	79.5	1.167	83.5	1.312	83	1.604	177	7.646	91.5	1.167	16.2	0.646	12
8. Thai Pop/S_3-29 × PCB/S_6-11	-0.167	86	0.333	90	-0.021	90.5	4.438	147	4.979	65	2.17	17.5	0.479	13
9. Thai Pop/S_3-1 × PCB/S_6-13	-0.688	82.5	-0.708	87.5	-0.771	87.5	9.875	157	5.104	65.5	0.77	19.2	-0.31	11.9
10. Thai Pop/S_3-8 × PCB/S_6-13	-1.021	79.5	-0.708	85.5	-0.438	85	8.208	188	0.938	88	-0.56	16.5	-0.31	11
11. Thai Pop/S_3-16 × PCB/S_6-13	1.646	85	1.458	90.5	1.562	90.5	-2.458	147.5	-1.062	66.5	0.104	18	0.688	11.5
12. Thai Pop/S_3-17 × PCB/S_6-13	1.146	82	1.625	86	1.396	86	-4.292	152.5	·11.73*	52.5	0.77	17.5	0.188	11.3
13. Thai Pop/S_3-20 × PCB/S_6-13	0.146	78	-0.208	82.5	-0.104	82.5	-1.125	172	-1.396	74.5	-0.73	17.5	0.188	11.5

Crosses	DT		DPS		DS		PH		EH		EL		ED	
	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean
14. Thai Pop/S_3-26 × PCB/S_6-13	-0.188	84	0.292	88	-0.438	89	3.375	152.5	5.104	63.5	0.44	16.5	0.688	11.7
15. Thai Pop/S_3-28 × PCB/S_6-13	0.312	84.5	-0.208	89.5	0.062	90	-18.95**	169	0.938	72.5	-1.89	18.2	-1.48*	10.8
16. Thai Pop/S_3-29 × PCB/S_6-13	-1.354	80	-1.542	85	-1.271	85	5.375	170.5	-1.062	72	1.104	18	0.354	11
17. Thai Pop/S_3-1 × PCB/S_6-39	1.188	84	2.042	89.5	2.292	89.5	-4.812	152	1.583	59	1.396	18.5	0.5	12
18. Thai Pop/S_3-8 × PCB/S_6-39	0.354	83.5	0.042	88.5	-0.375	89.5	-4.979	156	2.583	72	0.062	18	-1	11
19. Thai Pop/S_3-16 × PCB/S_6-39	-1.479	80	-0.792	86	-0.875	86.5	0.354	169	-5.083	83	1.229	18.5	0	12.5
20. Thai Pop/S_3-17 × PCB/S_6-39	-1.479	84.5	-2.63*	89	-2.542*	90.5	-6.479	123	·13.08*	45	-0.10	15.5	0.5	10
21. Thai Pop/S_3-20 × PCB/S_6-39	1.021	83	1.542	88	1.458	88.5	8.188	166.5	5.75	65	0.396	18.5	0	12.15
22. Thai Pop/S_3-26 × PCB/S_6-39	-0.312	79.5	-0.458	85	0.125	85	0.188	172.5	7.75	82	-0.44	18.1	0	11.8
23. Thai Pop/S_3-28 × PCB/S_6-39	-0.812	83	-0.958	87.5	-1.375	89	17.35**	148	4.083	57	0.729	17	0.833	11.5
24. Thai Pop/S_3-29 × PCB/S_6-39	1.521	85.5	1.208	90	1.292	91	-9.812	140	-3.583	59	-3.27	13.1	-0.83	10.2
SE(sij) / SE	1.309	1.31	1.235	1.24	1.222	1.22	6.227	6.23	5.479	5.48	1.782	1.78	0.651	0.67

Table 4. Cont'd

Crosses	NK/R		TSW		Yi (t/ha)		POP%		PE		TQ	
	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean
1. Thai Pop/S_3-1 × PCB/S_6-11	2	39.5	-14.90	165	-0.23	3.30	-15.37**	74	-3.53**	24.53	-0.087	2.51
2. Thai Pop/S_3-8 × PCB/S_6-11	-1.5	35.8	1.77	175	-0.25	3.83	9.80**	96	2.28**	28.40	0.248	2.74
3. Thai Pop/S_3-16 × PCB/S_6-11	-2	34	-6.56	200	0.08	6.08	-3.87**	86.5	1.49**	26.28	-0.08	2.49
4. Thai Pop/S_3-17 × PCB/S_6-11	-3.167	36.5	-9.90	210	0.28	3.69	7.30**	99	4.34**	28.40	0.015	2.82
5. Thai Pop/S_3-20 × PCB/S_6-11	0.167	37	10.94	190	0.77	5.60	-6.95**	70.5	-3.26**	19.14	-0.18	2.50
6. Thai Pop/S_3-26 × PCB/S_6-11	-1.333	37.5	10.10	225	0.85	5.15	-6.78**	86.5	-7.18**	25.81	0.66**	2.34
7. Thai Pop/S_3-28 × PCB/S_6-11	0.833	34	-13.23	180	-2.98	4.21	0.97	89	3.52**	26.78	-0.19	2.89
8. Thai Pop/S_3-29 × PCB/S_6-11	5.0*	35.5	21.77	220	1.48	5.23	14.89**	82	2.33**	13.26	-0.39	3.22
9. Thai Pop/S_3-1 × PCB/S_6-13	-0.312	35.5	-6.15	160	-1.73	5.59	13.85**	96	5.02**	30.81	0.107	2.73
10. Thai Pop/S_3-8 × PCB/S_6-13	0.188	33.5	-19.48	180	-0.37	4.76	-11.48**	94.5	-2.28**	28.08	-0.103	2.61
11. Thai Pop/S_3-16 × PCB/S_6-13	0.688	36.5	32.19**	170	-0.93	5.98	-3.65**	56	-7.33**	12.56	0.229	2.70
12. Thai Pop/S_3-17 × PCB/S_6-13	1.021	37	-21.15	220	-0.54	5.35	-23.98**	99.5	-6.48**	25.56	0.079	2.41
13. Thai Pop/S_3-20 × PCB/S_6-13	-3.146	35.5	4.69	210	-1.45	5.24	5.52**	93.25	0.66	22.88	-0.141	2.18

Crosses	NK/R		TSW		Yi (t/ha)		POP%		PE		TQ	
	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean
14. Thai Pop/S_3-26 × PCB/S_6-13	0.854	31	18.85	205	-0.98	5.06	5.19**	98.5	5.16**	22.12	-0.335	2.25
15. Thai Pop/S_3-28 × PCB/S_6-13	-1.979	36.5	15.52	182.5	7.50**	5.74	4.44**	97.25	0.78	28.44	-0.045	2.59
16. Thai Pop/S_3-29 × PCB/S_6-13	2.688	37.5	-24.48*	215	-1.50	5.57	10.10**	93.5	4.45**	13.12	0.209	2.81
17. Thai Pop/S_3-1 × PCB/S_6-39	-1.688	38.5	21.042	225	1.96	5.77	1.51*	98.25	-1.48**	20.78	-0.02	1.84
18. Thai Pop/S_3-8 × PCB/S_6-39	1.312	37.5	17.708	175	0.62	5.43	1.68*	97.5	-0.001	22.02	-0.145	1.73
19. Thai Pop/S_3-16 × PCB/S_6-39	1.312	38	-25.63*	175	0.86	6.38	7.51**	99.25	5.83**	24.25	-0.149	2.31
20. Thai Pop/S_3-17 × PCB/S_6-39	2.146	34	31.04**	205	0.27	6.89	16.68**	95.5	2.13**	16.82	-0.094	2.48
21. Thai Pop/S_3-20 × PCB/S_6-39	2.979	36.5	-15.625	185	0.68	5.43	1.43*	88.5	2.59**	16.11	0.321	2.64
22. Thai Pop/S_3-26 × PCB/S_6-39	0.479	37.5	-28.96*	235	0.13	5.52	1.59*	97.5	2.01**	17.11	-0.327	2.55
23. Thai Pop/S_3-28 × PCB/S_6-39	1.146	34	-2.292	190	-4.52*	4.57	-5.41**	85.5	-4.31**	14.53	0.233	3.17
24. Thai Pop/S_3-29 × PCB/S_6-39	-7.69**	23	2.708	215	0.02	4.65	-24.99**	53.25	-6.78**	7.68	0.181	3.03
SE(sij) /SE	2.295	2.30	11.89	11.89	1.96	2.01	0.696	1.02	0.412	0.44	0.230	0.22

*, ** indicate significant at 5% and 1% respectively;

DT= Days to 50% tasseling, DPS= Days to 50% pollen shedding, DS= Days to 50% silking, PH=Plant height, EH= Ear height, EL= Ear length, ED= Ear diameter, NK/R=Kernel number per row, TSW= Thousand grain wt., Yi= Yield (t/ha), Pop%= Popping percentage, PE= Popping expansion; TQ=Taste of Quality scale (1=very good, 5=very poor).

pollen shading, silking, plant height and ear height together with significant positive sca against 1000 grain weight, popping percentage and popping expansion where it also possesses positive sca for kernel number per row and yield. In general, the crosses involved both good general combiners and or at least one good combiner showed high SCA effects are due to additive × additive and additive × dominant gene action. These results agreed with the earlier findings of Hussain *et al*. (2003) in maize.

Conclusion

The parental line Thai Pop /S_3-20 has been identified as the best general combiner due to its good combining ability effects and also its ability to transmit characters to their progenies for most of the characters. The crosses Thai Pop/S_3-17 × PCB/S_6-39 and Thai Pop/S_3-20 × PCB/S_6-39 were marked out as good combinations for yield and quality trait along with high mean performances, could be used in future breeding program to develop high yielding popcorn hybrids with desirable qualities.

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