Research Article

Combining ability analysis for yield and its components in popcorn (*Zea mays* var. *everta* Sturt.)

A. Vijayabharathi[1], C.R. Anandakumar and R.P. Gnanamalar

Abstract

A line x tester set was obtained by crossing 8 lines with 3 testers in popcorn. The resultant 24 derived F_1s were evaluated along with 11 parents to estimate general and specific combining ability variances and effects for 14 characters. The results showed predominant role of non-additive gene action for all the characters studied. Based on both *per se* and *gca,* the genotypes UPC 5, UPC 4, UPC 1 among lines and Amber popcorn, Bangalore popcorn among the testers were proved as good general combiners for yield and quality traits. High *per se*, significant *sca,* standard heterosis exhibited by three hybrids *viz.,* UPC 9 x Amber popcorn, UPC 8 x Amber popcorn and UPC 1 x UPC 6 could be used for exploitation of heterosis for yield and quality characters.

Key words: Combining ability, *gca, sca*, popcorn

Introduction

In India, commercial popcorn is currently cropped on a fairly small scale. However, the genetic improvement work in a minor crop like popcorn is neglected in India and there is good scope for its improvement in near future. Now the use of popcorn as a snack food has been increasing continuously throughout the world. Repeated buying of a brand name of popcorn depends very much on its quality. Popcorn quality is measured primarily by the expansion volume and number of unpopped kernels (Song *et al.,* 1991). The popping characteristics of popcorn have not been fully investigated. Results from classical quantitative genetics and traditional statistical analysis have shown that popping characteristics are quantitatively inherited, controlled by multiple genes (Clary, 1954; Ashman, 1983; Ziegler, 2001), influenced by environmental effects (Li *et al*., 2003) and popping methods (Dofing *et al.,* 1990). Both additive and dominant genetic effects play very important roles in the inheritance of popping characteristics (Dofing *et al*., 1991).

Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai – 625 104, Tamil Nadu, India,

Email: bharathi8783@gmail.com

Modern plant breeding aims to improve yield and quality together. In breeding programmes, it is desirable to predict expansion volume with different variables of popcorn genotypes. Yield is a very important trait in popcorn as in other corn types. The most important factor affecting yield in popcorn is genotype (Pajic, 1990; Pajic and Babic, 1991). A narrow genetic base is undesirable for popcorn breeding because a certain level of parental divergence is needed to create productive hybrids. Considering the above facts, the present investigation has been undertaken to estimate combining ability of parents and select the good general combiners to use in the future breeding programme.

Materials and methods

The present investigation was conducted at Agricultural College and Research Institute, Madurai. Three testers (*viz.,* Amber popcorn, Bangalore popcorn and UPC 6) and eight lines (*viz.,* UPC 1, UPC 4, UPC 5, UPC 7, UPC 8, UPC 9, UPC 10 and UPC 11) were crossed during *kharif* season of 2007 to produce 24 hybrids. Test materials were raised in a Randomized Block Design with two replications during *rabi/summer* 2007-08. Seeds of each cross and their parents were sown in a row of 3 m length in each with the spacing of 60 cm between the rows and 30 cm between plants. Observations were recorded on 10 plants selected at random in each replication for 14 characters *viz.,* plant height, days to 50% tasseling, days to 50% silking, days to maturity, harvest index, number of kernel rows per cob, number of kernels per row, cob length, cob girth, cob weight, 100-kernel weight, degree of popping, popping expansion and single plant yield. To measure the degree of popping and popping expansion volume, based on the studies of Srinivasa Reddy *et al.* (2003) was followed with slight modifications. Combining ability analysis was done following standard procedure of Kempthorne (1957).

Results and discussion

The variances due to crosses, lines, testers and line x tester were significant for most of the characters except for days to 50% tasseling and number of kernels per row for lines, days to days to 50% tasseling, days to 50% silking, days to maturity and degree of popping for testers, while differences due to interactions were significant for all the characters except days to 50% tasseling, days to 50% silking and days to maturity. The estimates of *gca* and *sca* variances revealed greater importance of the later for all the characters indicating predominance of non-additive gene action in inheritance of these traits. The ratio of *gca* and *sca* was less than one, indicating more *sca* variance.

The estimates of *gca* effects revealed that the line UPC 5 (15.0) and Amber popcorn (14.11) as tester were proved as good general combiners for single plant yield (Table 1). In addition to these, UPC 5 was also good general combiner for number of kernel rows per cob (0.54), cob length (0.64), cob weight (18.74), 100-kernel weight (1.72) and important quality characters *viz.,* degree of popping (3.56) and popping expansion (48.40). Amber popcorn was also exhibited good general combining ability for days to 50% tasseling (-1.13), harvest index (4.09), number of kernel rows per cob (0.58), number of kernels per row (2.44), cob length (0.78), cob girth (0.53), cob weight (15.45) and 100-kernel weight (1.03). Bangalore popcorn was found to be good general combiner for plant height (-1.91), degree of popping (1.69) and popping expansion (24.20). The *gca* for other characters revealed that parents UPC 4 for days to 50% silking (-3.62), days to maturity (-1.69), number of kernel rows per cob (0.65), cob length (1.14), cob girth (0.87) and 100-kernel weight (1.29); UPC 6 for plant height (-5.60), days to 50% tasseling (-1.44) and days to maturity (-1.20). Crosses involving these parents might produce heterotic hybrids with high mean performance for respective traits.

Similar results of non-additive gene action for different characters have been reported by many workers, *viz.,* Subramanian and Subbaraman (2006) for plant height; Gowhar Ali *et al.* (2007) for days to 50% tasseling; Dar *et al.* (2007) for days to 50% silking, number of kernels per row, cob length, cob girth and100-kernel weight; Lata *et al.* (2006) for days to maturity; Dubey *et al.* (2001) for harvest index; Mahto and Ganguli (2003) for number of kernel rows per cob; Immanuel Selvaraj *et al.* (2006) for cob weight; Carlos Alberto Scapim *et al.* (2002) and Freitas Júnior *et al.* (2006) for popping expansion and Amit Dadheech and Joshi (2007) for single plant yield.

The estimates of *sca* effects revealed that the cross UPC 9 x Amber popcorn recorded significant *sca* in desirable direction for important qualitative as well as quantitative characters *viz.,* popping expansion (37.48), harvest index (4.41), cob weight (13.78) and single plant yield (13.11) (Table 2). UPC 8 x Amber popcorn recorded positive, significant *sca* for quantitative characters *viz.,* harvest index (9.83), cob girth (0.60), cob weight (20.06) and single plant yield (19.90). While hybrids UPC 1 x UPC 6 and UPC 7 x Amber popcorn recorded significant mean, *sca* and standard heterosis for three characters each.

From this study it can be concluded that all the characters were governed by non-additive gene action. The cross combinations showing high *sca* effects for yield and quality characters, if found to be a combination of both parents having good general combining ability can be utilized in the hybrid development programme for exploitation of heterotic vigour. Therefore best combiners such as UPC 5, UPC 10 and Amber popcorn could be utilized in future breeding programme.

References

Amit Dadheech and V.N. Joshi. 2007. Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize (*Zea mays* L.). *Indian J. Agric. Res.,* **41(3)**: 210-214.

Ashman, R. B. 1983. Popcorn. Plant Disease Control, Bulletin BP-4 Cooperative Extension Service, Purdue University.

Carlos Alberto Scapim, Ronald José Barth Pinto, Antônio Teixeira do Amaral Júnior, Freddy Mora and Thatiana Silva Dandolini. 2006. Combining ability of white grain popcorn populations. *Crop Breed. Appl. Biotech.,* **6**: 136-143.

Clary, G. 1954. A study of the inheritance of expansion in popcorn. Ph. D., Thesis. Purdue University, West Lafayette, IN.

Dar, S.A., Gowhar Ali, A.G. Rather and M.N. Khan. 2007. Combining ability for yield and maturity traits in elite inbred lines of maize. *Int. J. Agric. Sci.,* **3(2)**: 290-293.

Dofing, S.M., M.A. Thomas-Compton and J.S. Buck. 1990. Genotype x popping method interaction for expansion volume in popcorn. *Crop sci.,* **30**: 62-65.

Dofing, S.M., N. D′ Croz-Mason and M.A. Thomas-Compton. 1991. Inheritance of expansion volume and yield in two popcorn x dent corn crosses. *Crop Sci.,* **31**: 715-718.

Dubey, R.B., V.N. Joshi and N.K. Pandiya. 2001. Heterosis and combining ability for quality, yield and maturity traits in conventional and non-conventional hybrids of maize (*Zea mays* L.). *Indian J. Genet.,* **61(4)**: 353-355.

Freitas Júnior, S.P., A.T. Amaral Júnior, M.G. Pereira. 2006. Combining ability in popcorn by circulant diallel. *Pesq. Agropec. Bras*., **41**: 1599-1607.

Gowhar Ali, A.G. Rather, A. Ishfaq, S.A. Dar, S.A. Wani and M.N. Khan. 2007. Gene action for grain yield and its attributes in maize (*Zea mays* L.). *Int. J. Agric. Sci.,* **3(2)**: 278-281.

Immanuel Selvaraj, C., P. Nagarajan and D. Vijendra Das. 2006. Heterotic expression and combining ability analysis for qualitative and quantitative trains in inbreds of maize (*Zea mays* L.). *Crop Res.,* **32(1)**: 77-85.

Kempthorne, O. 1957. An Introduction to Genetic Statistics. John Wiley and Sons, Inc. NewYork, p. 458-471.

Lata, S., G. Katna, J.K. Sharma and Jai Dev. 2006. Components of variation, combining ability and heterosis studies for yield and its related traits in maize (*Zea mays* L.). *Crop. Improv.,* **33(2)**: 151-155.

Li, Y.L., S.W. Wu, S.Z. Niu and Z.Q. Li. 2003. Analysis of combining ability of popcorn with normal corn inbreds belonging to different heterotic groups*. J. Henan Agric. Univ.,* **37**: 1-5 (In Chinese).

Mahto, R.N. and D.K. Ganguli. 2003. Combining ability analysis in inter varietal crosses of maize (*Zea mays* L.). *Madras Agric. J.,* **90(1-3)**: 29-33.

Pajic, Z. 1990. Popcorn and sweet corn breeding. International advanced course maize breeding, production, marketing in Mediterranean countries maize 90. September 17 to October 13, Belgrade, Yugoslavia.

Pajic, Z. and M. Babic. 1991. Interrelation of popping volume and some agronomic characteristics in popcorn hybrids. *Genetica,* **2:** 137-144.

Song, A., S.R. Eckhoff, M. Paulsen and J.B. Litchfield. 1991. Effects of kernel size and genotype on popcorn popping volume and number of unpoped kernels. *Cereal chemistry,* **68(5)**: 464-467.

Srinivasa Reddy, V., Y. Chandramohan, N.V. Rao and L. Krishna. 2003. Character association and path analysis in popcorn (*Zea mays* var. *everta*). *Crop. Res.,* **25(2)**: 297-300.

Subramanian, A. and A. Subbaraman. 2006. Combining ability analysis for yield and its contributing traits in maize (*Zea mays* L.). *Indian J. Agric. Res.,* **40 (2)**: 131-134.

Ziegler, K. E. 2001. Popcorn. In: Hallauer AR (ed.), Specialty Corns. CRC Press, Boca Raton,. p: 199-224.

*****

Table 1. General combining ability (*gca*) of parents for yield and quality traits

	PH	DFT	DFS	DM	HI	NRC	NKR	CL	CG	CW	HKW	DP	PE	SPY
Lines														
L_1	-1.24	0.27	0.85	0.64	0.16	-1.12**	-0.51	-0.10	0.19	5.77**	3.49**	-1.67*	-37.71**	6.85**
L_2	16.70**	-0.89	-3.62**	-1.69**	-2.63**	0.65**	-0.95	1.14**	0.87**	-0.61	1.29**	-3.33**	-86.71**	-1.43
L_3	14.92**	0.44	0.35	1.03	-0.50	0.54*	0.38	0.64*	0.07	18.74**	1.72**	3.56**	48.40**	15.00**
L_4	2.31*	-0.06	0.02	0.31	-0.12	0.77**	0.10	-0.15	0.25	9.28**	0.10	-2.84**	-18.10**	9.34**
L_5	-11.58**	-0.73	-0.48	-0.30	-3.36**	-1.12**	-0.51	-0.01	-0.30*	-20.94**	0.49	-0.33	-22.60**	-19.85**
L_6	9.92**	-0.40	0.02	0.20	-2.33**	0.32	-0.56	-0.63*	-0.60**	4.57*	-3.23**	1.61	69.79**	3.79*
L_7	-16.97**	0.27	1.02	-0.47	3.67**	0.43	0.10	-1.43**	0.39**	-2.37	-0.89*	3.78**	24.07**	-1.29
L_8	-14.08**	1.10	1.85	0.26	5.11**	-0.46*	1.94*	0.54	-0.86**	-14.45**	-2.97**	-0.78	22.85**	-12.42**
SE	1.00	0.86	0.92	0.57	0.52	0.21	0.83	0.29	0.13	1.64	0.41	0.79	2.21	1.47
Testers														
T_1	7.51**	-1.13*	-0.72	-0.53	4.09**	0.58**	2.44**	0.78**	0.53**	15.45**	1.03**	-0.13	-29.87**	14.11**
T_2	-1.91**	2.56**	1.64**	1.72**	-3.70**	-0.12	0.23	-0.13	-0.26**	-8.73**	-1.37**	1.69**	24.20**	-9.71**
T_3	-5.60**	-1.44*	-0.92	-1.20**	-0.39	-0.46**	-2.67**	-0.65**	-0.27**	-6.72**	0.34	-1.56**	5.67**	-4.40**

* Significant at 5% level; ** Significant at 1% level

L_1	-	UPC 1	L_5	-	UPC 8	T_1	Amber popcorn
L_2	-	UPC 4	L_6	-	UPC 9	T_2	Bangalore popcorn
L_3	-	UPC 5	L_7	-	UPC 10	T_3	UPC 6
L_4	-	UPC 7	L_8	-	UPC 11		

Table 2. Specific combining ability (*sca*) of hybrids for yield and quality traits

Hybrids	PH	DFT	DFS	DM	HI	NRC	NKR	CL	CG	CW	HKW	DP	PE	SPY
$L_1 \times T_1$	-0.17	0.29	0.39	1.08	1.74	-0.91*	-0.99	0.82	0.02	-1.03	2.45**	0.46	27.65**	-1.18
$L_1 \times T_2$	-25.26**	2.10	2.52	0.83	-1.38	0.12	-1.45	-0.56	-0.80**	-13.60**	-3.40**	0.81	25.25**	-12.93**
$L_1 \times T_3$	25.43**	-2.39	-2.91	-1.92	-0.36	0.79*	2.44	-0.26	0.77**	14.63**	0.94	-1.27	-52.90**	14.81**
$L_2 \times T_1$	-20.62**	-0.54	1.95	-0.25	-11.16**	-1.03**	-2.39	-0.67	-0.41	-20.57**	2.58**	1.96	-10.35*	-18.82**
$L_2 \times T_2$	17.30**	1.77	-4.01*	0.17	1.29	0.35	2.83	0.48	0.02	8.37**	-1.55*	-1.19	4.58	9.99**
$L_2 \times T_3$	3.32	-1.23	2.05	0.08	9.87**	0.68	-0.44	0.18	0.38	12.20**	-1.02	-0.77	5.77	8.83**
$L_3 \times T_1$	19.16**	-0.38	-0.62	-0.14	-1.22	0.42	2.29	-0.23	0.19	14.41**	0.17	2.57	-9.13*	11.43**
$L_3 \times T_2$	-3.42	-1.56	-1.47	-1.22	1.04	0.46	-3.18*	-1.96**	-0.38	-17.26**	-2.36**	-2.91*	34.81**	-12.35**
$L_3 \times T_3$	-15.74**	1.94	2.09	1.36	0.18	-0.88*	0.89	2.19**	0.18	2.85	2.19**	0.34	-25.68**	0.92
$L_4 \times T_1$	31.94**	0.12	0.22	-0.08	0.23	1.20**	-0.44	0.12	0.67**	8.88**	0.45	-0.55	-20.63**	6.91*
$L_4 \times T_2$	-35.81**	-0.06	0.86	-0.50	5.60**	-0.43	0.44	-0.06	-0.09	-1.35	-0.25	3.15*	-3.86	-4.35
$L_4 \times T_3$	3.88*	-0.06	-1.08	0.58	-5.83**	-0.77*	0.00	-0.06	-0.58*	-7.52*	-0.20	-2.60	24.49**	-2.56
$L_5 \times T_1$	3.16	-0.71	-1.28	-0.80	9.83**	0.08	2.84	0.91	0.60*	20.06**	1.15	-0.04	-8.46*	19.90**
$L_5 \times T_2$	3.08	-0.39	0.86	0.61	-7.75**	0.12	2.21	2.29**	0.39	-1.84	2.74**	-1.02	-52.53**	-6.06*
$L_5 \times T_3$	-6.24**	1.10	0.42	0.19	-2.08*	-0.21	-5.06**	-3.20**	-0.99**	-18.22**	-3.90**	1.06	60.99**	-13.84**
$L_6 \times T_1$	2.66	-0.04	-0.78	0.19	4.41**	-0.03	-1.44	0.20	-0.03	13.78**	-1.99**	-1.99	37.48**	13.11**
$L_6 \times T_2$	11.41**	0.77	1.86	0.61	-0.63	-0.65	1.27	0.01	-0.25	-3.96	1.34	2.70	-9.25*	-2.04
$L_6 \times T_3$	-14.07**	-0.73	-1.08	-0.80	-3.78**	0.68	0.17	-0.21	0.28	-9.82**	0.65	-0.72	-28.23**	-11.07**
$L_7 \times T_1$	-25.45**	1.29	0.72	1.03	4.61**	-0.47	2.06	-0.10	-0.13	-3.50	0.11	-0.32	-12.47**	-2.27
$L_7 \times T_2$	10.97**	-0.39	0.36	-0.22	-4.10**	0.57	-4.56**	-0.96	0.29	-1.40	0.09	1.20	5.14	-0.32
$L_7 \times T_3$	14.48**	-0.90	-1.08	-0.81	-0.51	-0.10	2.50	1.06*	-0.16	4.89	-0.20	-0.88	7.33	2.59
$L_8 \times T_1$	-10.67**	-0.04	-0.61	-1.03	-8.44**	0.75*	-1.93	-1.06*	-0.92**	-32.03**	-4.92**	-2.09	-4.08	-28.37**
$L_8 \times T_2$	21.74**	-2.23	-0.97	-0.28	5.93**	-0.54	2.43	0.76	0.81**	31.04**	3.40**	-2.75	-4.14	28.06**
$L_8 \times T_3$	-11.07**	2.27	1.59	1.31	2.51*	-0.21	-0.50	0.29	0.10	0.99	1.53*	4.84**	8.22*	0.32
SE	1.74	1.48	1.59	0.99	0.90	0.36	1.44	0.51	0.23	2.84	0.71	1.36	3.83	2.54