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Combining ability estimates in virus resistant and susceptible lines of chilli (*Capsicum annuum* L.)

C. Venkataramana[1], K. Madhavi Reddy[2], A.T. Sadashiva[2] and M. Krishna Reddy[3]

[1]Division of Horticulture, GKVK, University of Agricultural Sciences, Bangalore, [2]Division of Vegetable Crops, Indian Institute of Horticultural Research, Bangalore, [3]Department of Plant Pathology, Indian Institute of Horticultural Research, Bangalore. Email: cvr_venkat@yahoo.com.

Abstract

Combining ability analysis of 8 x 8 diallel cross (including reciprocals) was carried out in chilli, involving cucumber mosaic virus (CMV) resistant and susceptible lines. The variances for general combining ability (gca) and specific combining ability (sca) were highly significant for all the characters, suggesting the importance of both additive and non-additive gene action. The sca variance played an important role in the genetic control of days to 50% flowering, days to 50% ripening , fruit width, plant height, plant spread, number of fruits per plant, green fruit yield per plant and per cent CMV incidence. On the contrary additive gene action was observed for fruit length. The genotype VR-27 was judged to be the best general combiner for fruit yield per plant and Perennial, Punjab Lal, Punjab Gucchedar and Pant C-1 proved to be good general combiners for per cent CMV incidence. The crosses Punjab Gucchedar x Pant C-1 and Tiwari x EG-174 had greater sca effect for fruit yield. These two crosses may directly be used for commercial cultivation after further testing over a range of environments. Fifteen of the twenty eight crosses had significant reciprocal effect for green fruit yield per plant. Hence, the influence of maternal effect on the economic traits is evident in the present material.

Key words: *Capsicum annuum* L., diallel, combining ability, reciprocal effect, CMV

Introduction

Chilli (*Capsicum annuum* L.) is one of the versatile crops grown in India for its green fruits as vegetable and red ripe form as spice. Many food industries have been extracting oleoresin from chilli. Oleoresin from chilli is used in the preparation of processed products and in pharmaceutical preparations. In India, chilli is grown in an area of 0.956 million hectares with an annual production of 0.945 million tonnes with average productivity of 0.9 t ha^{-1} (Peter, 1999). Even- though India ranks first in area and production, the productivity is very low compared to other countries like Japan (3.6 t ha^{-1}) and Korea (2.0 t ha^{-1}).

The low productivity of chilli is mainly due to the attack of various pathogens like fungi, bacteria and virus. Incidence of viral diseases is a major production constraint contributing to low yields and reduced fruit quality (Villalon, 1981). About 45 viruses are known to be infecting peppers (*Capsicum* spp.), of which 21 have been reported to be infecting chilli in India. Among these Potato virus Y (PVY), Chilli veinal mottle virus (CVMV), Tobacco etch virus (TEV), Pepper vein banding virus (PVBV), Pepper veinal mottle virus (PVMV), belonging to poty virus group and cucumber mosaic virus, belonging to cucumo virus are economically important viruses having greater host range (Hobbs *et al.*, 2000). Cucumber mosaic virus is one of the most prevalent and wide spread viruses infecting hot peppers (Duriat, 1996). Breeding CMV resistant varieties/hybrids has been recognized as the most effective and economic way of disease control. However, in India, few varieties like Pant C-1, Tiwari and Punjab Lal were developed for resistance to CMV, their acceptability in the country is less. Presently, chilli breeding programme aims at evolving high yielding disease resistant varieties and it may be carried out effectively, only if information on combining ability of recipient and donor parent is available. In addition to elucidating the nature and magnitude of various types of gene actions involved in the expression of quantitative traits, the combining ability studies provide useful information in the selection of parents, in terms of performance of the hybrids. In this direction, the present study was under taken to assess the combining ability of CMV resistant and susceptible lines for yield and its components.

Materials and methods

The experimental material comprised of eight genetically diverse chilli lines exhibiting resistance and susceptible reaction to the cucumber mosaic virus. Six lines (Perennial (P_1), Punjab Lal (P_2), Punjab Gucchedar (P_3), Pant C -1 (P_4), Tiwari (P_5), and VR-27 (P_6)) were resistant and rest were susceptible (PMR-76 (P_7) and EG-174 (P_8)). These were crossed in 8 x 8 diallel mating design (including reciprocals) during *rabi*, 2000. The parental lines were selected based on their reaction to artificial inoculation of CMV and field performance with respect to yield and resistance to viruses. These lines were maintained by continuous selfing at vegetable breeding block, Division of Vegetable Crops, IIHR, Bangalore. All the eight parents, 56 hybrids, susceptible check Arka Abhir and a commercial check CH-2507 (Pro-Agro Nunhems Seeds) were evaluated during *kharif*, 2001 in randomized block design replicated thrice. Each genotype was represented by two rows; in each row 10 seedlings were planted at a distance of 60 cm between rows and 45 cm between plants. Standard

recommended cultural practices were followed during the experimentation. Observations were recorded on plant height (cm), plant spread (cm), fruit length (cm), fruit width (cm), number of fruits per plant and green fruit yield per plant (g) from five randomly selected plants in each genotype and for days to 50% flowering and days to 50% ripening recorded based on number of days for flowering and ripening on fifty per cent population in each genotype. Observation on CMV incidence was recorded at full fruiting stage under natural field conditions. Healthy and diseased plants were counted separately and per cent incidence was calculated for each line. Results based on symptomatology were confirmed in the presence or absence of virus, more specifically in resistant reaction by enzyme-linked immunosobent assay (ELISA). The general combining ability (gca) of parents and specific combining ability (sca) of crosses were computed by adopting method I and model I of Griffing (1956). Eight parents involved in the investigation were classified as low (L), average (A) and high (H) with respect to their overall gca effect as per the procedure given by Arunachalam and Bandyopadyay (1979).

Results and discussion

Combining ability of a genotype indicates its potentiality in cross combination with other genotype. Estimation of general combining ability effects assumes importance in the choice of parents to obtain superior recombinants or to exploit heterosis depending on the nature of combining ability.

Analysis of variance revealed significant differences for all characters, indicating wide genetic variability among genotypes. The mean squares due to general and specific combining ability (gca and sca) and reciprocal effects were highly significant (Table 1) for all traits. This indicates that both additive and non-additive types of gene action were involved in the inheritance of these traits. Hence, improvement of these traits may be brought about by recurrent selection or selective diallel mating system (Saraladevi and Arumugam, 1999).

All the characters except fruit length recorded greater magnitude of sca variance than gca variance. It reveals that non-additive gene action was preponderant over additive in the inheritance of these traits. Majority of the characters were governed by the non-additive gene action (Table 1) which is in conformity with the findings of Nandadevi *et al*. (2003) and Lohithaswa *et al*. (2000).

The estimates of gca effects (Table 2) indicated VR-27 to be the best general combiner for green fruit yield per plant (72.98 g), which also showed significant gca effect in desirable direction for all the traits except per cent CMV incidence. The parents Perennial, Punjab Lal, Punjab Gucchedar and Pant C-1 proved to be good general combiners for per cent CMV incidence in desired direction. Two parents VR-27 and PMR-76 showed good general combining ability for days to 50% flowering, while PMR-76, VR-27 and EG-174 were good general combiners for days to 50% ripening. VR-27 and PMR-76 showed significant positive gca effects for fruit length. For traits, plant height and plant spread, EG-174, PMR-76 and VR-27 were adjudged as the best combiners due to their high positive gca effects. The genotypes which showed significant gca effect in desirable direction for various characters can be used in multiple crosses and segregating population obtained thereof for identifying and selecting segregants which pool all the favourable alleles distributed among the parents.

In 28 direct crosses, 17 crosses showed significant and desirable sca effect for days to 50% flowering, 15 for days to 50% ripening, two for fruit length, seven for fruit width, three for plant height, nine for plant spread, 11 for number of fruits per plant, 13 for green fruit yield per plant (g) and also for per cent CMV incidence. The cross PMR-76 x EG-174 (-7.60) exhibited the highest negative sca effect for early flowering, followed by Punjab Lal x Pant C-1 (-4.82); while the best specific combination for green fruit yield per plant was Punjab Gucchedar x Pant C-1 (181.41) followed by Tiwari x EG-174 (169.36). By observing the gca effects of the parents and sca effects of the crosses, it can be concluded that to obtain heterotic hybrid at least one of the parents must be an

Table 1. Relative magnitude of mean squares for general, specific and reciprocal combining ability and genetic components

Source of variation	d f	Days to 50% flowering	Days to 50% ripening	Fruit length (cm)	Fruit width (cm)	Plant height (cm)	Plant spread (cm)	No. of fruits per plant	Green fruit yield per plant (g)	Per cent CMV incidence
Progenies	63	47.79**	100.49**	8.95**	0.13**	254.00**	165.25**	7662.22**	80815.65**	1156.71**
Parents	7	47.76**	67.42**	10.76**	0.13**	556.32**	272.08**	1978.22**	14773.80**	175.61**
Hybrids	55	42.21**	98.71**	8.22**	0.13**	210.30**	153.73**	8395.31**	85610.59**	1267.10**
Parents vs hybrids	1	355.27**	429.76**	36.60**	0.20**	541.45**	50.97*	7191.84**	279386.92**	1952.74**
F_1s	27	43.65**	88.35**	8.58**	0.16**	239.51**	124.23**	5096.50**	48694.73**	1046.37**
Reciprocals	27	34.36**	108.28**	8.05**	0.10**	185.27**	178.89**	10407.85**	121865.55**	1530.13**
F_1s vs reciprocal	1	214.88**	120.02	2.95*	0.06**	97.42*	273.23**	43124.36**	103454.72**	125.05**
Error	126	0.39	3.11	0.62	0.02	23.53	12.89	50.23	59.61	9.60
Genetic components										
gca	7	13.39**	21.95**	19.49**	0.19**	359.33**	188.95**	217.60**	53997.35**	539.99**
sca	28	16.13**	34.80**	1.05**	0.03**	60.18**	45.08**	2465.75**	25149.91**	357.14**
Reciprocals	28	16.23**	35.08**	0.79**	0.02**	40.49**	31.62**	2739.74**	21962.49**	420.39**
Error	126	0.32	1.04	0.21	0.01	7.85	4.29	16.74	19.87	3.20
σ^2_{gca}		0.86	1.31	1.21	0.01	21.97	11.54	134.42	3373.59	22.29
σ^2_{sca}		15.99	33.77	0.84	0.02	52.34	40.78	2449.03	25130.04	353.93
$\sigma^2_{reciprocal}$		8.05	17.02	0.29	0.01	16.32	13.66	1361.49	10971.31	208.59
σ^2_{gca} / σ^2_{sca}		0.05	0.04	1.43	0.49	0.42	0.28	0.05	0.13	0.06

** Significant at *P*=0.01 * Significant at *P*=0.05

Table 2. General combining ability estimates for various characters studied in chilli

Parent	Days to 50% flowering	Days to 50% ripening	Fruit length (cm)	Fruit width (cm)	Plant height (cm)	Plant spread (cm)	Number of fruits per plant	Green fruit yield per plant (g)	Per cent CMV incidence
Perennial	-0.03	0.60*	-1.38	-0.09**	-5.08**	-4.33**	-8.06**	-90.94**	-6.84**
Punjab Lal	0.87**	-0.23	0.43	0.04*	-0.84	1.19*	-10.78**	-6.29**	-3.14**
Punjab Gucchedar	0.77**	0.94**	-0.32	-0.11**	-3.69**	-4.31**	-4.13**	-51.59**	-2.24**
Pant C-1	0.27**	2.02**	-1.29	-0.01	-2.27**	-0.62	20.91**	23.50**	-1.65**
Tiwari	0.76**	0.15	-0.83	-0.01	-2.41**	-1.99**	0.01	-44.66**	3.93**
VR-27	-1.69**	-1.25**	1.43**	0.06**	1.37**	1.43**	9.44**	72.98**	8.75**
PMR-76	-1.11**	-1.39**	1.16**	-0.01	3.26**	4.59**	6.19**	42.42**	0.18
EG-174	0.18	-0.83**	0.79**	0.24**	9.67**	4.06**	-13.65**	54.58**	1.02**
G i	0.08	0.24	0.11	0.02	0.66	0.48	0.96	1.04	0.22
CD (*P*=0.05)	0.16	0.48	0.21	0.04	1.31	0.95	1.90	2.05	0.44
CD (*P*=0.01)	0.21	0.63	0.29	0.05	1.73	1.26	2.51	2.72	0.57

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

Table 3. Specific combining ability estimates for different traits

Hybrid	Days to 50% flowering	Days to 50% ripening	Fruit length (cm)	Fruit width (cm)	Plant height (cm)	Plant spread (cm)	Number of fruits per plant	Green fruit yield per plant (g)	Per cent CMV incidence
P_1 x P_2	-0.20	-1.25*	0.65	0.06	-1.56	4.25**	-29.26**	-114.32**	5.74**
P_1 x P_3	1.58**	1.75**	-0.46	-0.06	-2.87	-0.26	-17.73**	1.84	13.82**
P_1 x P_4	3.23**	4.83**	0.08	-0.19**	5.06**	4.60**	-68.25**	-106.28**	4.13**
P_1 x P_5	1.56**	6.04**	-0.35	-0.07	-11.24**	-7.49**	29.36**	-13.00**	-2.88*
P_1 x P_6	-0.47*	1.77**	0.46	-0.17**	0.51	-4.51**	8.08**	2.01	-15.19**
P_1 x P_7	-4.05**	-6.58**	0.35	0.08	0.61	-3.55**	61.83**	125.06**	-1.44
P_1 x P_8	-1.34**	-4.31**	-2.10**	0.00	2.35	3.41**	22.36**	19.36**	-2.08
P_2 x P_3	-1.37**	-1.25*	0.12	0.17**	-3.98*	-3.96**	-0.68	-8.79**	7.99**
P_2 x P_4	-4.82**	-4.50**	-0.80*	-0.22**	-3.07	-0.14	57.15**	100.52**	1.82
P_2 x P_5	2.00**	2.20**	-0.27	0.09*	0.71	6.21**	4.28	19.22**	-2.53*
P_2 x P_6	-2.87**	-3.56**	0.14	0.10*	2.91	3.41**	11.25**	133.00**	-8.63**
P_2 x P_7	1.04**	0.41	0.55	-0.01	1.87	-4.01**	-19.48**	-27.02**	9.64**
P_2 x P_8	0.25	1.52*	0.34	-0.02	-0.95	1.82	-23.55**	4.23	-11.18**
P_3 x P_4	-0.20	2.33**	0.53	0.12**	-6.57**	-3.27**	41.22**	181.41**	-8.00**
P_3 x P_5	-3.03**	-1.95**	1.39**	0.06	-2.03	-5.69**	-22.65**	-57.10**	-10.38**
P_3 x P_6	-2.57**	-6.89**	0.01	-0.06	-3.54*	-2.29	80.90**	58.72**	15.26**
P_3 x P_7	-1.49**	-1.25*	0.42	-0.06	-4.88**	1.18	-4.47	-11.82**	-2.91*
P_3 x P_8	-2.12**	-3.49**	0.22	-0.11*	-2.83	4.81**	-21.45**	-147.10**	-9.58**
P_4 x P_5	-1.87**	-4.20**	0.27	-0.01	7.58**	-0.07	-20.75**	-112.06**	21.92**
P_4 x P_6	-1.73**	-2.14**	0.22	0.10*	2.88	4.29**	21.20**	8.18**	-0.87
P_4 x P_7	4.15**	3.16**	0.79*	0.20**	2.36	2.90*	29.46**	129.37**	-8.13**
P_4 x P_8	-3.33**	-2.39**	0.03	0.07	-1.63	-2.04	-13.37**	-86.74**	-1.48
P_5 x P_6	-2.09**	0.70	0.46	-0.07	2.54	-0.56	-38.45**	-85.35**	21.85**
P_5 x P_7	-1.59**	-0.67	-1.13**	-0.07	5.31**	4.81**	-10.69**	44.60**	-12.02**
P_5 x P_8	-1.85**	-5.52**	0.63	0.20**	0.38	-3.02*	29.30**	169.36**	-12.42**
P_6 x P_7	0.77**	-1.32*	0.17	-0.08	-7.04**	-3.12*	-23.77**	-147.90**	-13.26**
P_6 x P_8	1.48**	4.87**	0.00	0.05	-5.24**	0.46	-7.21**	62.10**	16.16**
P_7 x P_8	-7.60**	5.68**	0.51	-0.06	-10.87**	-10.63**	-0.21	71.26**	38.41**
Sij	0.23	0.64	0.40	0.05	1.75	1.30	2.56	2.78	1.12
CD (*P*=0.05)	0.44	1.25	0.78	0.10	3.43	2.54	5.01	5.45	2.93
CD (*P*=0.01)	0.57	1.60	1.00	0.12	4.45	3.26	6.44	7.01	2.23

**: Significant at 1% level; *: Significant at 5% level ; P_1 = Perennial; P_2 = Punjab Lal; P_3 = Punjab Gucchedar; P_4 = Pant C-1; P_5 = Tiwari, P_6 = VR- 27; P_7 = PMR-76; P_8 = EG-174

average or good general combiner as also mentioned by Jagadeesh (1995). Further, the sca effect of most of the heterotic crosses for yield and its components (Table 3) indicated that these specific cross combinations involved either one or both the good gca parents. As such these crosses are of specific significance as, besides being highly heterotic, they have good *per se* performance and involve good gca parents. The cross Tiwari x EG-174 recorded highly significant sca effects for early flowering, early ripening, fruit width, number of fruits per plant, green fruit yield per plant and per cent CMV incidence. Hence this cross may be advanced through conventional breeding procedures, coupled with screening and selection for resistance

towards isolation of high yielding and disease resistant varieties.

The estimates of reciprocal effects for 28 indirect crosses are shown in Table 4. Eighteen cross combinations had significant reciprocal effects in desired direction for early flowering, out of which PMR-76 x Punjab Gucchedar and PMR-76 x Tiwari displayed highest (-5.16) reciprocal effect. The same was also observed in Punjab Lal x Perennial and PMR-76 x Punjab Gucchedar for days to 50% ripening. Only two crosses recorded positive and significant reciprocal effect for fruit length and fruit width. The cross PMR-76 x Punjab Gucchedar (48.46) exhibited the highest positive reciprocal effect for number of fruits per plant, followed by EG-174 x Punjab Gucchedar (35.85) , whereas PMR-76 x VR-27 (181.41) recorded highest green fruit yield per plant followed by EG-174 x VR-27 (169.36). Seven combinations displayed significant and desired reciprocal effects for per cent CMV incidence, out of which, Tiwari x Pant C-1(-40.00) recorded the highest. Similar

Table 4. Reciprocal effects on different traits

Hybrid	Days to 50% flowering	Days to 50% ripening	Fruit length (cm)	Fruit width (cm)	Plant height (cm)	Plant spread (cm)	Number of fruits per plant	Green fruit yield per plant (g)	Per cent CMV incidence
P_2 x P_1	-1.66**	-7.50**	-1.08**	-0.20**	-0.03	0.81	-2.36	-12.94**	-1.56
P_3 x P_1	-2.33**	-0.66	-0.30	-0.01	3.21	2.25	-40.73**	13.33**	14.47**
P_3 x P_2	-2.33**	-4.50**	0.37	-0.04	-3.94*	-8.23**	-46.86**	-142.41**	1.75
P_4 x P_1	-2.16**	-3.50**	0.42	-0.04	-2.79	1.95	-22.93**	21.97**	0.32
P_4 x P_2	-1.60**	-4.00**	-0.68*	-0.05	1.54	3.86**	35.36**	38.39**	2.17
P_4 x P_3	-2.17**	-5.66**	-1.60**	0.10	4.33*	5.25**	-95.87**	-320.40**	3.91
P_5 x P_1	-1.66**	-1.83*	-0.09	0.19**	0.43	0.52	-66.59**	- 7.49*	10.00**
P_5 x P_2	1.12**	-0.83	0.53	0.10	-5.13*	-0.78	14.62* *	98.21**	8.94**
P_5 x P_3	1.83**	4.16**	1.29**	0.07	-7.99**	7.97**	-15.44**	24.07**	1.22
P_5 x P_4	2.50**	5.00**	-0.23	-0.13*	4.03*	7.90**	-24.79**	1.28	-40.00**
P_6 x P_1	-1.83**	-3.83**	-0.15	-0.12*	-0.52	3.14*	6.79*	59.76**	2.50
P_6 x P_2	-1.33**	-0.66	0.28	-0.02	-0.97	0.59	0.13	5.06	-7.23**
P_6 x P_3	-1.83**	0.50	0.27	-0.14*	1.00	-1.41	6.78*	109.30**	2.56
P_6 x P_4	3.00**	0.50	-0.77*	-0.03	-2.04	-2.47	-64.88**	-99.37**	-9.54**
P_6 x P_5	-0.33	2.66**	0.59	-0.10	10.74**	2.38	11.89* *	97.59**	39.80**
P_7 x P_1	-3.16**	-1.33	-0.01	-0.05	-3.18	1.08	-69.42**	23.00**	-7.69**
P_7 x P_2	2.50**	2.80**	-0.35	-0.13*	12.20**	5.07**	10.91**	134.51* *	14.36**
P_7 x P_3	-5.16**	-7.00**	0.54	-0.09	-1.36	0.07	48.46**	128.30 **	-4.95**
P_7 x P_4	-1.33**	1.66*	0.12	0.16**	5.85**	1.91	-44.02**	4.24	0.92
P_7 x P_5	-5.16**	-5.83**	-0.07	-0.13*	5.66**	6.00**	-23.58**	-34.35**	2.23
P_7 x P_6	3.00**	6.16**	0.52	-0.08	0.33	-0.61	-26.79**	181.41**	-4.33
P_8 x P_1	-4.83**	-4.50**	0.35	-0.03	2.97	0.18	-12.68**	-39.30**	7.89**
P_8 x P_2	-2.60**	-2.50**	1.03**	-0.01	-5.40**	-6.06**	-3.64	-87.70**	2.50
P_8 x P_3	-2.16**	-6.33**	-0.20	-0.13*	-0.34	0.27	35.85**	68.41**	5.00*
P_8 x P_4	1.50**	5.83**	0.57	-0.08	-0.06	0.87	16.54* *	18.04**	-1.57
P_8 x P_5	1.17**	0.50	-0.01	-0.10	-2.18	-4.70**	-23.88**	-184.10**	-8.33**
P_8 x P_6	3.33**	4.83**	-1.05**	-0.09	2.96	1.33	-13.41**	169.36**	8.40**
P_8 x P_7	-4.66**	-1.83*	0.46	0.02	2.03	6.49**	-24.45**	-147.50**	-39.59**
R_{ij}	0.26	0.72	0.32	0.06	1.98	1.47	2.89	3.15	2.27
CD (*P*=0.05)	0.51	1.43	0.63	0.12	3.92	2.91	5.72	6.23	5.95
CD (*P*=0.01)	0.68	1.89	0.84	0.16	5.19	3.85	7.57	8.25	4.49

**: Significant at 1% level; *: Significant at 5% level ; P_1 = Perennial; P_2 = Punjab Lal; P_3 = Punjab Gucchedar; P_4 = Pant C-1; P_5 = Tiwari, P_6 = VR -27; P_7 = PMR-76; P_8 = EG-174

Table 5. Pooled gca effects of the parents used in 8 x 8 diallel crosses of chilli

Character	Perennial	Punjab Lal	Punjab Gucchedar	Pant C-1	Tiwari	VR-27	PMR-76	EG-174
Days to 50 % flowering	-1	0	0	0	0	-1	-1	0
Days to 50 % ripening	0	-1	0	0	0	-1	-1	-1
Fruit length (cm)	-1	0	-1	-1	-1	0	0	0
Fruit width (cm)	-1	0	-1	-1	-1	0	-1	0
Plant height (cm)	-1	-1	-1	-1	-1	0	0	0
Plant spread (cm)	-1	0	-1	-1	-1	0	0	0
Number of fruits per plant	-1	-1	-1	0	0	0	0	-1
Green fruit yield per plant(g)	-1	-1	-1	0	-1	0	0	0
Per cent CMV incidence	-1	-1	-1	-1	0	0	0	0
+ve	1	4	2	4	4	7	6	7
-ve	8	5	7	5	5	2	3	2
gca status	L	L	L	L	L	H	H	H

L=Low combiner; H=High combiner

reciprocal effects for days to 50% flowering, plant height, number of fruits per plant and fruit yield were observed by Saraladevi and Arumugam (1999). The importance of maternal effect of economic traits is evident in the present investigation as also observed by Wynne and Halward (1989) and Vindhiyavarman (2000) in groundnut.

Among the eight parents, VR-27, PMR-76 and EG-174 were classified as 'high' with respect to their overall gca status and Perennial, Punjab Lal, Punjab Gucchedar, Pant C-1 and Tiwari could be grouped under 'low' class. None of the genotypes could be grouped under average class. The potential genotypes from the pooled gca analysis could be used in future breeding programs. These results are in conformity with the findings of Nandadevi *et al*. (2003)

From the foregoing discussion, it may be concluded that, among all the hybrids, Punjab Gucchedar x Pant C-1 and Tiwari x EG-174 were resistant to CMV with highest yield potential. Hence, it may be directly used as CMV resistant / tolerant hybrid after further testing over a range of environments, to establish their stability of performance and incorporation of genetic male sterility, to facilitate commercial hybrid seed production.

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