Indian J. Genet., **63**(2): 148-152 (2003)

Studies on heterosis and combining ability in bottlegourd [*Lagenaria siceraria* (Molina) Standl.]

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(Received: January 2003; Revised: May 2003; Accepted: May 2003)

Abstract

Nine parental lines of bottlegourd and their 36 F_1 hybrids obtained from half diallel were studied to investigate the extent of heterosis and general and specific combining ability effects for yield and yield attributing characters. The mean squares due to GCA and SCA were significant for all the characters. The ratio, $\hat{\sigma}^2$ gca/ $\hat{\sigma}^2$ sca suggested that non-additive gene action had greater role in the inheritance of all the characters except for average weight of marketable fruit, node at which first female flower appeared, number of branches per plant and vine length, where additive gene action had played an important role. Out of the nine parents, UL-4 was adjudged the best general combiner as it depicted high gca effect in desirable direction for most of the traits. Regarding sca effects, UL-2 × UL-4 showed highest sca effects for total fruit yield and UL-2 × UL-10 for days to first harvest. The extent of heterosis over the three best crosses for total fruit yield per plant (68.44-91.02% over better parent and 80.94-89.47% over check variety) revealed that there was a great scope of realizing higher yield in bottlegourd through heterosis breeding. The cross combination UL-2 × UL-4 registered the highest economic heterosis (89.47%) for total fruit yield and other characters including earliness.

Keywords: Bottlegourd, heterosis, combining ability

Introduction

Bottlegourd [*Lagenaria siceraria* (Molina) Standl.] is one of the important cucurbits grown throughout the country for its tender fruits. It is highly cross-pollinated crop due to monoecious and andromonoecious [1&2] nature and exhibits high heterosis in its crosses [3&4] which suggests a great scope of improvement through heterosis breeding. The important step for exploitation of heterosis is to study the general combining ability of the parents and specific combining ability of hybrids. Although some information is available about heterosis and combining ability but they are relevant to the specific region, genetic material involved and environmental conditions. Therefore, this study was conducted to generate information about nature and magnitude of heterosis and general and specific combining effects for different economic characters in a diallel cross system (excluding reciprocals) using nine parents of bottlegourd.

Materials and methods

The experimental plant material consisted of eight monoecious lines *viz.*, UL1, UL-2, UL-5, UL-4, UL-6, UL-10, UL-7 and Pusa Naveen and one andromonoecious line *viz.* INGR-99009 of bottlegourd. All monoecious lines were long-fruited however, the fruit of andromonoecious line was small and rectangular. All the genotypes were crossed in all possible combinations, excluding reciprocals, during summer-2000 to produce F_1 seeds by hand pollination. In next summer, 36 F_1s hybrids and 9 parental lines were sown in randomized block design with three replications. All treatments were grown in 3 meter long single row called plot, maintaining row to row and plant to plant distance of 3.0m and 50cm, respectively. Five plants were selected and tagged for recording the observations on different characters *viz.* total yield per plant (kg), number of fruits per plant, fruit length (cm), average weight of marketable fruit (kg), days to anthesis of first female flower, node at which first female flower appeared, days to first harvest, number of branches per plant and vine length (m). All the cultural operations and plant protection measures were carried out as per schedule of crop. The combining ability analysis was calculated by the method suggested by Griffing [5]. Heterosis was calculated over the better parent and the standard check i.e. hybrid "Warad" of Mahyco Hybrid Seed Co.

Results and discussion

The analysis of variance for combining ability is presented in Table 1. A perusal of the table revealed that mean squares due to GCA and SCA were significant for all the characters. This indicates variation in GCA of parents and SCA of crosses and significant

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Table 1. Analysis of variance for combining ability for the nine characters in 9 × 9 diallel cross of bottlegourd

Source of variation	df	Total fruit yield per plant (kg)	Number of fruits per plant	Fruit length (cm)	Average weight of marketable fruit (kg)	Days to anthesis of first female flower	Node at which first female flower appeared	Days to first harvest	Number of branches per plant	Vine length (m)
GCA	8	0.641**	1.794**	45.872**	0.014*	20.696**	0.974**	40.028**	0.358**	0.384
SCA	36	0.441**	1.286**	6.555**	0.010*	3.196**	1.305**	8.570**	0.639**	0.541
Error	88	0.088	0.277	0.465	0.005	0.297	0.037	1.033	0.034	0.016
∂^2 g		0.018	0.046	3.574	0.000	1.591	@	2.860	@	@
$\partial^2 s$		0.353	1.009	6.090	0.005	2.898	1.268	7.537	0.605	0.525
$\partial^2 g/\partial^2 s$		0.050	0.045	0.586	-	0.548	@	0.379	@	@

*, ** Significant at 5% and 1%, respectively; @indicates minus value.

combination of additive and non-additive gene effects in the expression of the characters. The ratio of $\hat{\sigma}^2$ g/ $\hat{\sigma}^2$ s was lesser than one for all the characters except average weight of marketable fruit(kg), node at which first female flower appeared, number of branches per plant and vine length(m), thereby indicating preponderance of non-additive variance in expression of these traits. Another study [6] observed non-additive gene action for all the characters except for node at which first female flower appeared. Other workers [7&8] observed that gca were dominant over sca effects for most of yield related characters. However, some workers [9,10] observed that both additive and non-additive gene action were involved in the expression of yield related characters. The disparity may be due to the different genetic backgrounds of the material studied.

The results of these studies suggested that heterosis breeding was suitable for all the characters including average weight of marketable fruit (kg), node at which first female flower appeared, number of branches per plant and vine length (m), which could be improved by simple selection.

Estimates of general combining ability effects (Table 2) showed that parent UL-4 was good general combiner for most of the traits *viz.*, total yield per plant(kg), number of fruits per plant, fruit length(cm), number of branches per plant and vine length(m) followed by parents UL-2 and UL-7 which were good general combiners for varying set of 4 characters each. Parents UL-5, UL-6, UL-10, Pusa Naveen and INGR-99009 were good general combiners for one character each.

From specific combining ability effects (Table 3), it was observed that out of 36 cross combinations, 6 crosses for total yield per plant, 8 for number of fruits per plant, 13 for fruit length(cm), 1 for average weight of marketable fruit(kg), 10 for days to anthesis of first female flower, 16 for node number at which first female flower appeared, 11 for days to first harvest, 10 for number of branches per plant and 8 for vine length(m) exhibited significant SCA effects in desirable direction indicating presence of non-additive type of gene interaction. Thus, it indicates the possibility of exploitation of hybrid vigor in the all characters studied. The SCA

Tabl 2. Estimates of GCA effects of the parents for different characters in 9 × 9 diallel cross of bottlegourd

Parents	Total fruit yield per plant (kg)	Number of fruits per plant	Fruit length (cm)	Average weight of marketable fruit (kg)	Days to anthesis of first female flower	Node at which first female flower appeared	Days to first harvest	Number of branches per plant	Vine length (m)
UL-1	0.03	0.08	0.16	−0.02	0.92**	0.01	0.84**	−0.10	0.03
UL-2	−0.02	−0.09	0.67**	0.02	−3.31*	−0.57*	−4.90*	−0.21*	−0.24*
UL-5	−0.04	−0.03	−0.43*	−0.01	0.68**	0.25**	1.06**	0.01	0.12**
UL-4	0.53**	0.85**	1.16**	−0.05*	0.13	0.32**	−0.04	0.29**	0.12**
UL-6	0.12	0.23	0.70**	−0.04	0.04	0.03	0.85**	−0.05	−0.16*
UL-10	−0.36*	−0.59*	0.94**	0.04	0.61**	0.16**	1.16**	−0.02	−0.02
UL-7	0.01	0.08	1.92**	−0.00	0.04	−0.39*	0.79**	0.30**	0.34**
Pusa Naveen	−0.18*	−0.21	0.02	−0.00	−0.56*	0.01	−0.41	−0.15*	−0.24*
INGR-99009	−0.09	−0.33*	−5.12*	0.06**	1.43**	0.18**	0.64*	−0.08	0.04
S.E. (gi)	0.08	0.15	0.19	0.02	0.16	0.06	0.29	0.05	0.04
SE. (gi-gi)	0.13	0.22	0.29	0.03	0.23	0.08	0.43	0.08	0.05

*, ** Significant at 5% and 1% respectively.

Table 3. Estimates of specific combining ability (sca) effect for different characters in 9 × 9 diallel cross of bottlegourd

Crosses	Total yield/plant (kg)	Number of fruits/ plant	Fruit length (cm)	Av. weight of marketable fruit (kg)	Days to anthesis of first female flower	Node at which first female flower appeared	Days to first harvest	Number of branches/ plant	Vine length (m)
UL-1 × UL-2	0.72**	1.93**	2.39**	–0.20**	1.29*	–0.07	0.78	1.69**	1.90**
UL-1 × UL-5	–0.04	–0.46	–0.91	0.09	0.63	0.31	0.42	–0.40*	–0.64**
UL-1 × UL-4	–0.83**	–1.20*	1.90**	0.02	0.37	–1.29**	0.59	–0.47**	–0.54**
UL-1 × UL-6	0.21	0.01	–3.38**	0.04	3.80**	0.13	2.16*	–0.40*	–0.09
UL-1 × UL-10	0.11	–0.10	–1.35*	0.05	0.09	–0.27	–1.94*	0.31	–0.16
UL-1 × UL-7	–0.40	–0.77	0.94	0.07	1.73**	–0.71**	–0.70	0.05	–0.45**
UL-1 × PN	0.30	0.73	3.44**	–0.09	–2.47**	–1.05**	–1.64	–0.36*	–0.26*
UL1 × INGR-99009	1.78**	2.84**	0.65	–0.14*	–1.79**	–0.82**	–1.62	0.43	1.15**
UL-2 × UL-5	–0.16	–0.10	–0.49	–0.08	0.53	–0.45*	3.63**	–0.49**	0.01
UL-2 × UL-4	1.32**	1.43**	–1.14	0.03	–1.99**	–0.38*	–3.07**	–0.63**	–0.27*
UL-2 × UL-6	–0.66*	–1.36**	–0.49	0.17*	–1.97**	0.04	–2.10*	–0.16	–0.13
UL-2 × UL-10	–0.32	–0.60	–4.59**	0.07	–2.47**	–0.49**	–5.60**	0.08	–0.05
UL-2 × UL-7	0.16	0.53	–3.17**	–0.03	1.30*	0.93**	–0.76	–0.51**	–0.44**
UL-2 'x PN	0.17	0.09	0.40	0.03	–2.24**	–0.21	–1.44	–0.06	–0.09
UL-2 × INGR 99009	–0.39	–0.39	1.08	–0.08	3.98**	–1.58**	6.85**	–0.06	–0.31*
UL-5 × UL-4	1.15**	2.23**	2.24**	–0.09	–0.79	–0.08	–0.10	2.42**	1.99**
UL-5 × UL-6	0.12	0.18	–2.25**	–0.01	1.10*	–1.45**	–2.66**	–0.51**	0.04
UL-5 × UL-10	–0.08	–0.33	1.65*	0.07	0.13	1.28**	–0.37	–0.47**	–0.33**
UL-5 × UL-7	0.75**	1.33**	–0.87	–0.09	–0.03	0.24	–1.99*	1.27**	1.17**
UL-5 × PN	0.29	0.23	2.37**	0.04	–0.43	–0.03	0.40	–0.01	–0.10
UL-5 × INGR 99009	–0.53	–0.52	2.98**	–0.09	–1.55**	–1.80**	–5.98**	–0.28	–0.79**
UL-4 × UL-6	0.12	0.57	–2.24**	–0.07	–1.75**	0.42*	–1.16	0.94**	–0.24*
UL-4 × UL-10	–0.83**	–1.07*	–0.01	–0.06	–1.39**	–2.45**	–1.87*	0.52**	–0.54**
UL-4 × UL-7	0.35	0.86	–2.86**	–0.09	–0.62	–1.03**	–0.96	1.19**	1.06**
UL-4 × PN	0.39	0.69	–0.82	–0.02	0.32	0.17	0.77	–0.55**	–0.20
UL-4 × INGR-99009	–1.42**	–2.07**	1.59*	0.07	–0.87	1.33**	–3.01**	–0.49**	–0.44**
UL-6 × UL-10	0.45	1.01*	2.11**	–0.13	–0.03	0.97**	–0.82	–0.47**	–0.15
UL-6 × UL-7	0.45	1.07*	1.73**	–0.10	–0.53	–0.60**	–2.38*	0.13	–0.20
UL-6 × PN	–0.30	–0.10	3.30**	–0.11	0.67	–0.88**	–1.32	1.32**	1.26**
UL-4 × INGR-99009	–0.03	0.09	0.25	–0.07	0.69	0.76**	–0.97	–0.22	–0.31**
UL-10 × UL-7	0.55*	0.96*	2.29**	–0.11	0.04	–0.67**	–0.36	0.37*	0.94**
UL-10 × PN	0.27	0.73	–2.74**	–0.13	1.57**	0.12	–0.43	0.10	–0.16
UL-10 × INGR-99009	0.28	0.38	0.61	–0.03	1.65**	–0.18	3.66**	–0.24	0.95**
UL-7 × PN	–0.46	–0.94	0.68	0.06	–0.79	0.55**	–2.12*	–0.56**	–0.54**
UL-7 × INGR-99009	–0.01	–0.43	3.96**	0.11	1.29*	1.78**	2.16*	0.36*	–0.18
PN × INGR-99009	–0.02	–0.13	0.73	–0.01	–2.11**	–1.76**	–0.37	0.22	0.14
S.E. (Sij)	0.27	0.48	0.62	0.07	0.50	0.18	0.93	0.17	0.12
S.E. (Sij-Sik)	0.40	0.71	0.92	0.10	0.74	0.26	1.37	0.25	0.17

*, ** Significant at 5% and 1% level, respectively

effects showed that best specific combination was UL-2 × UL-4 for total yield per plant, UL-5 × UL-4 for number of fruits per plant; UL-10 × UL-7 for fruit length(cm), UL-7 × INGR-99009 for average weight of marketable fruit(kg), UL-2 × Pusa Naveen for days to anthesis of first female flower, UL-4 × UL-10 and UL-2 × INGR-99009 for node number at which first female flower appeared, L2 × UL-10 for days to first harvest, UL-5 × UL-4 for number of branches per plant and for vine length(m).

Several workers [3,4,7,9&11] have also studied specific combining ability in this crop. From these studies, it is evident that sca effects of certain crosses were related with gca of their parents as the best cross combination for most of the characters involved at least one parent with high or average gca effects for particular traits. Similar results have been reported by [3] in bottlegourd and [10] in bittergourd.

Range of mean values of characters of parents, F_1 hybrids and per cent heterosis are given in Table 4. The mean of F_1 crosses was higher than those of

Table 4. Range and mean of parents and hybrids and three best heterotic cross combinations for nine characters in bottle gourd

		Total fruit yield/plant (kg)	Number of fruits/ plant	Fruit length (cm)	Average weight of marketable fruit (kg)	Days to anthesis of first female flower	Node at which first female flower appeared	Days to first harvest	Number of branches/ plant	Vine length (m)
Range	Parents	1.28-3.15	1.27-3.93	16.67-38.07	0.80-1.05	57.33-66.80	6.57-9.87	63.87-79.00	4.67-5.33	3.08-3.87
	Hybrids	1.24-4.04	1.40-6.00	28.47-38.00	0.61-0.97	57.07-67.93	5.60-9.40	63.47-78.27	4.87-8.27	3.25-6.11
Range of heterosis	BP	3.11-91.02	7.50-143.33	0.36-16.38	0.00-8.03	−0.32-4.42	−1.02-38.88	−0.44-7.92	1.23-72.22	1.67-64.75
(%) over	SP	1.86-89.47	6.52-95.65	4.91-40.05	1.96-39.34	−0.11-9.32	−0.85-28.21	−0.74-11.36	1.18-45.88	0.00-75.48
No. of heterotic	BP	5	7	4	1	5	21	15	11	9
Cross over	SP	18	15	36	34	14	25	9	13	8
Top parent on mean value		UL-4	UL-4	UL-4	INGR-99009	UL-2	UL-7	UL-2	INGR-99009	UL-7
Three top F_1s with heterosis % over BP		UL-5 × UL-7 (91.02)	UL-1 × UL-2 (143.33)	UL-1 × PN (16.38)	UL-2 × UL-6 (8.03)	PN × INGR 99009 (−4.42)	UL-4 × UL-10 (−35.88)	UL-5 × UL-6 (−7.92)	UL-5 × UL-4 (72.22)	UL-5 × UL-4 (64.75)
		UL-1 × INGR-99009 (79.17)	UL-5 × UL-7 (140.74)	UL-5 × PN (9.21)		UL-1 × PN (−3.38)	PN × INGR 99009 (−33.82)	UL-6 × UL-7 (−7.53)	UL-4 × UL-7 (46.67)	UL-1 × UL-2 (59.77)
		UL-1 × UL-2 (68.44)	UL-1 × INGR-99009 (130.56)	UL-10 × UL-7 (6.34)		UL-4 × UL-10 (−3.20)	UL-5 × INGR-99009 (−31.62)	UL-5 × INGR-99009 (−7.05)	UL-5 × UL-7 (42.67)	UL-5 × UL-7 (42.17)
Three top F_1s with heterosis % over SP		UL-2 × UL-4 (89.47)	UL-5 × UL-4 (95.65)	UL-10 × UL-7 (40.05)	UL-7 × INGR-99009 (39.34)	UL-2 × PN (−4.42)	UL-4 × UL-10 (−28.21)	UL-2 × UL-10 (−11.36)	UL-5 × UL-4 (45.88)	UL-5 × UL-4 (75.45)
		UL-1 × INGR-99009 (84.48)	UL-1 × INGR-99009 (80.43)	UL-6 × UL-7 (37.10)	UL-2 × UL-6 (36.38)	UL-2 × UL-6 (−3.38)	UL-2 × INGR 99009 (−28.21)	UL-2 × UL-4 (−9.50)	UL-4 × UL-7 (29.41)	UL-1 × UL-2 (59.77)
		UL-5 × UL-4 (80.94)	UL-2 × UL-4 (67.39)	UL-6 × PN (35.87)	UL-2 × UL-10 (33.08)	UL-2 × UL-4 (−3.20)	PN × INGR-99009 (−23.08)	UL-2 × PN (−7.73)	UL-5 × UL-7 (25.88)	UL-5 × UL-7 (58.24)
Best heterotic F_1 hybrid		UL-2 × UL-4	UL-5 × UL-4	UL-10 × UL-7	UL-7 × INGR-99009	UL-2 × PN	UL-4 × UL-10	UL-2 × UL-10	UL-5 × UL-4	UL-5 × UL-4

the parents in all the characters except in fruit length (cm) and average weight of marketable fruit (kg). The range of heterosis percentage in F_1 crosses varied from 3.11 to 91.02 and 1.86 to 89.47 for total fruit yield per plant, 7.50 to 143.33 and 6.52 to 95.65 for number of fruits per plant, 0.36 to 16.16 and 4.91 to 40.05 for fruit length(cm), 0 to 8.03 and 1.96 to 39.34 for average weight of marketable fruit(kg), −0.32 to −4.42 and −0.11 to −9.32 for days to anthesis of first female flower, −1.02 to −38.88 and −0.85 to −28.21 for node number at which first female flower appeared, −0.44 to 7.92 and −0.74 to −11.36 for days to first harvest, 1.23 to 72.22 and 1.18 to 45.88 for number of branches per plant and 1.67 to 64.75 and 0.00 to 75.48 for vine length(m) over their respective better parent and standard parent (Warad variety), respectively. Out of 36 hybrids, the significant heterotic effects over their respective better and standard parents were observed in 5 and 18 crosses for total fruit yield per plant, 7 and 15 for number of fruits per plant, 4 and 36 for fruit length (cm), 1 and 34 for average weight of marketable fruit (kg) 5 and 14 for days to anthesis of first female flower, 21 and 25 for node at which first female flower appeared, l5 and 9 for days to first harvest, 11 and 13 for number of branches per plant and 9 and 8 for vine length(m).

The best performing hybrids over the standard parent for different characters included UL-2 × UL-4 for total fruit yield per plant, UL-5 × UL-4 for number of fruits per plant, UL-10 × UL-7 for fruit length (cm), UL-7 × INGR-99009 for average weight of marketable fruit (kg), UL-2 × Pusa Naveen for days to anthesis of first female flower, UL-4 × UL-10 for node at which first female flower appeared, UL-2 × UL-10 for days to first harvest, UL-5 × UL-4 for number of branches per plant and for vine length (m).

In order of merit three hybrids namely UL-2 × UL-4, UL-I × INGR-99009 and UL-5 × UL-4 were observed to be the best performing hybrids for total fruit yield per plant and showed significant heterosis of 89.47, 84.48 and 80.94 per cent, respectively over standard parent. For earliness (days to first harvest) cross UL-2 × UL-10 displayed the maximum negative heterosis (−11.36%) over standard parent. The highest yielding hybrid i.e. UL-2 × UL-4 also recorded the third best heterotic performer for number of fruits per plant and for days to anthesis of first female flower and second best performer for days to first harvest.

The highest yield recorded in the best performing hybrid i.e. UL-2 × UL-4 could be attributed to its increased number of fruits per plant, fruit length (cm), days to anthesis of first female flower and days to first harvest. The second best hybrid was UL-1 × INGR-99009, which recorded 79.17 and 84.48 per cent heterosis over the better and standard parent, respectively. This cross was the product of monoecious and andromonoecious nature of parents and thus suggest the future possibility for inclusion of andromonoecious line in heterosis breeding programme. Though the andromonoecious line has poor shape but in crosses it gives the good quality of shape. The results of the present investigation are in conformity with the findings of other workers in bottlegourd [1,3&12] in bittergourd [14] in muskmelon [15]. The results from the present study suggest that it is useful to select parental lines having one or more important characters like higher fruit number, long fruit, early maturity, minimum days to anthesis of first female flower and more branches in a plant to achieve higher gains in the F_1 hybrids through heterosis breeding.

On the basis of the above results, the best performing hybrids i.e. UL-2 × UL-4 can be further tested and recommended for commercial cultivation to boost the fruit yield per unit area of bottlegourd as it recorded 89.47 per cent higher yield over the commercial growing hybrid "Warad."

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