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COMBINING ABILITY ANALYSIS FOR YIELD AND YIELD CONTRIBUTING TRAITS IN BITTER GOURD

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Abstract: *Combining ability was studied in diallel mating design using seven homozygous lines namely, DVBTG-903, DVBTG-7, IC-06309, VRBTG-423, VRBTG-12-2, IC-068296, DVBTG-448, IC-068316, DVBTG-1004 and Green Long Jaunpuri. Variance due to general and specific combing ability were significant among all the characters under studied. Among the parents, P_1, P_6, P_2, P_{10}, P_3 for node at which first staminate flowers anthesis, P_1, P_7, P_3, P_4, P_{10} and P_2 for days to first pistillate flower anthesis, P_5, P_8, P_3, P_7, P_1 and P_{10} for node at which first staminate flower appears. P_7, P_5, P_1, P_3, P_8 and P_{10} for node at first pistillate flower appears. P_2, P_6 and P_1 for fruit yield per plant were found good general combiners. However, in specific combining ability study, the crosses P_5xP_9 for node at which first pistillate flower appears, P_6xP_8 sex ratio male: female, P_1xP_5 for fruit length, P_4xP_{10} number of fruits per plant and P_1xP_8 fruit yield per plant exhibited high specific combining ability.*
Keywords: *Combing ability, bitter gourd.*

Introduction: Vegetables play an important role in the balanced diet by providing not only energy, but also by supplying vital protective nutrients like minerals, antioxidants, and vitamins. Consumption in sufficient quantity provides all required essential nutrients and a fair amount of fibres. Vegetables also play an important role in neutralizing the acids produced during digestion of proteins and fatty foods, and thus promote digestion and also prevents constipation. Apart from providing nutrition, vegetables provide protect against many diseases. eg. Bitter gourd is used for treating diabetes. Bioflavonoids which are compounds closely associated with vitamins are found in several vegetables and they increase the efficiency of vitamin c and protect the body from free radicals.

Bitter gourd (*Momordica charantia* L) is one of the important cucurbitaceous vegetables grown in our country. Among the cucurbits, it is considered a prized vegetable because of its high nutritive value especially ascorbic acid and iron. The somatic chromosome number of *Momordica charantia* is 2n=2x=22. Other species belonging to this genus are *M. dioca, M. cochinchinensis, M. balsamina, M. tuberosa, M. subangulata, M. denudata and M. macrocarpa*. The plant is a monocious annual climber, stem 5 angled and furrowed; tendrils simple or forked. Leaves are palmetely 5-9 lobed and 5-17 cm in diameter. Flowers axillary, solitary about 3 cm in diameter, calyx deeply 5 fid, corolla rotate, parted nearly to base, petals 5, filaments free and anther united. There are three short styles terminated by three bilobed stigma. Fruit is pendulous, fusiform ribbed with numerous tubercles and seed brownish with scarlet axil. Anthesis and anther dehiscence occur early in the morning. Selfing and crossing should be attempted in the forenoon preferably in early hours for crossing purpose. Female flower buds ready to open in the next 1-2 days are covered by small paper bags, like-wise male flower buds ready to open next morning are also covered. Pollination is carried out by rubbing anthers of freshly opened flowers against stigma of the protected pistillate flowers. The crossed flowers are covered as above for a few more days.

Breeding method for the improvement of a crop depends primarily on the nature and magnitude of gene actions involved in the expression of quantitative and qualitative traits. Combining ability analysis helps in the identification of parents with high general combining ability (GCA) and cross combinations with high specific combining ability (SCA) effects. Additive and non additive gene action in the parents, estimated through combining ability analysis may be useful in determining the possibility for commercial exploitation of heterosis. The present study is aimed to obtain the information on combining ability of 10 varieties and 45 hybrids (F_1) of bitter gourd for fruit yield and yield contributing characters.

Materials and Methods

Ten promising and diverse inbred lines/varieties of bitter gourd namely, DVBTG-903, DVBTG-7, IC-06309, VRBTG-423, VRBTG-12-2, IC-068296, DVBTG-448, IC-068316, DVBTG-1004 and Green Long Jaunpuri were taken for the present study. All the lines were hand-pollinated with each other to produce all possible combinations of F_1 hybrids in half-diallel fashion (Griffing). Pollen for crossing was obtained from freshly dehisced anther. The seeds of 45 F_1 hybrids and 10 parental lines (total of 55 genotypes) were sown in Vegetable Research Farm, Banaras Hindu University, Varanasi during summer 2014 in randomized complete block design with three replications to assess the performance of 45 F_1 hybrids and their 10 parental lines. The crop was planted in rows spaced at 3.0 meters with plant to plant spacing of 0.5 meter. The observations were recorded on randomly selected five plants for twelve economically important traits namely (1) Days to first staminate flower anthesis (2) Days to first pistillate flower anthesis (3) Node at which first staminate flower appears (4) Node at which first pistillate flower appears (5) Internodal length (cm) (6) Sex ratio male: female (7) Days to first fruit harvest (8) Vine length (m) (9) No. of primary branches per plant (10) Fruit length (cm.) (11) Fruit circumference (cm) (12) Average Fruit Weight (g.) (13) No. of fruits per plant (14) Fruit Yield per plant (Kg.) and Number of seeds /fruit. The mean data was subjected to analysis of combining abilities (gca and sca) as per model suggested by Griffing.

Results and Discussion

Analysis of variance for gca and sca presented in (Table-1) for general combining for various yield and yield contributing characters were highly significant for all the traits. In specific combining ability (sca) also they were highly significant for all the fifteen traits which indicated that both additive and dominant gene action perform important role in the expression of all the fifteen traits. General combining ability (gca) estimates are presented in (Table-2). The estimates of specific combining ability for 45 F_1 hybrids. Out of 45 crosses only 11 showed highly significant (sca) value in desirable direction for days to first staminate flower anthesis. P_6xP_{10} (-3.85), P_1xP_2 (-3.15) and P_5xP_8 (-2.74) were good combiners for days to first staminate flower anthesis. For days to first pistillate flower anthesis, cross P_6xP_9 (-4.29), P_2xP_3 (-3.31) and P_1xP_5 (-2.75) revealed significantly desirable (sca) effects. Out off 45 crosses 13 are showed desirable (sca) effect. For node number to first staminate flower appearance cross combinations P_2xP_8 (-1.32), P_8xP_9 (-1.26) and P_5xP_6 (-1.21) had the highest specific combining ability. For node number to first pistillate flower appearance cross combinations P_5xP_9 (-1.96), P_3xP_5 (-1.86) and P_8xP_{10} (-1.71) had the highest negative specific combining ability. For internodal length crosses P_4xP_5, P_9xP_{10} and P_2xP_{10} are shows desirable negative specific combining ability. P_6xP_8 (1.67), P_4xP_{10} (1.66) and P_3xP_{10} (1.36) were good combiners for sex ratio male: female. For days to first fruit harvest, negative crosses showed desirable combining ability. Cross P_2xP_3 (-5.44), P_2xP_7 (-4.80) and P_1xP_4 (-4.47) showed earliness. Out of 45 crosses 18 crosses showed desirable combining ability for days to first fruit harvest. For vine length cross combination P_7xP_9 (0.66), P_4xP_{10} (0.59) and P_2xP_3 (0.38) showed high specific combining ability. Among 45 cross combinations 3 showed highly significant (sca) values in vine length. For primary branches per plant crosses P_1xP_2 (4.92), P_1xP_7 (2.51) and P_7xP_9 (2.11) showed significant desirable direction. For fruit length, highly significant specific combining ability values were obtained for the crosses P_1xP_5 (2.78), P_3xP_4 (2.57) and P_2xP_6 (2.34). For fruit circumference cross P_1xP_5 (2.77), P_2xP_6 (1.87) and P_8xP_{10} (1.50) exhibited highly significant specific combining ability, out of 45 crosses, only 8 cross showed significant desirable (sca) effects. For average fruit weight positive crosses showed desirable combining ability. Crosses P_7xP_9 (12.88), P_1xP_2 (10.88) and P_4xP_5 (10.33) were good specific combiners. Out of 45 crosses 19 crosses showed desirable combining ability for average fruit weight. For number of fruits per plant, cross combination P_4xP_{10} (4.48), P_1xP_4 (4.32) and P_7xP_8 (4.04) showed high specific combining ability. Among 45 cross combinations, 9 showed highly significant (sca) values for number of fruits per plant. For fruit yield per plant, highly significant specific combining ability values were obtained from the crosses P_1xP_8 (0.42), P_6xP_8 (0.35) and P_7xP_9 (0.33) and for number of seeds/fruit crosses P_7xP_9, P_4xP_9 and P_2xP_9 showed positive significant desirable specific combining ability. Out of 45 crosses only 14 crosses showed significant desirable (sca) effects. Similar result is reported [1,2,3,4, 5, 6,7,8, 9 & 10].

Table-1: Analysis of variance (mean squares) for combining ability in methods-II model-I of diallel analysis in bitter gourd

Source of variation	Degree of freedom	Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Node at which first staminate flower appears	Node at which first pistillate flower appears	Internodal length (cm)	Sex ratio Male: Female	Days to first fruit harvest	Vine length (m)
GCA	9.00	101.09**	61.11**	12.14**	12.80**	0.44**	1.46**	52.48**	0.59**
SCA	45.00	2.90**	2.68**	0.87**	1.52**	0.69**	1.22**	8.08**	0.08**
Error	108.00	0.30	0.30	0.20	0.22	0.13	0.07	0.34	0.03

Table-1.1: Analysis of variance (mean squares) for combining ability in methods-II model-I of diallel analysis in bitter gourd

Source of variation	Degree of freedom	No. of primary branches per plant	Fruit length (cm.)	Fruit circumference (cm)	Average Fruit Weight (g.)	No. of fruits per plant	Fruit Yield per plant (Kg.)	Number of seeds /fruit
GCA	9.00	8.26**	4.71**	0.88**	45.32**	64.10**	0.20**	15.38**
SCA	45.00	5.90**	2.85**	1.04**	41.50**	10.87**	0.04**	7.54**
Error	108.00	0.34	0.26	0.25	0.92	1.92	0.01	0.40

Table-2: Estimation of specific combining ability (SCA) effect of 45 F_1 hybrids for 15 characters of bitter gourd

Hybrids	Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Node at which first staminate flower appears	Node at which first pistillate flower appears	Internodal length (cm)
P_1xP_2	-3.15 **	-1.74**	-0.55	-0.97 *	0.76 *
P_1xP_3	-1.41 **	0.74	-0.72	-1.21 **	0.81*
P_1xP_4	0.03	-1.39**	0.08	0.01	0.66*
P_1xP_5	-0.17	-2.75**	-0.13	-1.51 **	0.28
P_1xP_6	0.17	0.62	0.87 *	0.68	0.25
P_1xP_7	-1.01	-1.92**	-0.43	-0.10	-0.33
P_1xP_8	2.78**	1.02	-0.04	0.05	0.24
P_1xP_9	3.33**	2.72**	0.31	-0.22	-1.29 **
P_1xP_{10}	1.08 *	0.20	0.10	-0.79	-0.50
P_2xP_3	-1.62 **	-3.31 **	-0.55	-0.67	-0.38
P_2xP_4	1.64**	0.49	-0.46	1.66***	1.10 **
P_2xP_5	0.81	2.69 **	0.18	0.26	-1.38**
P_2xP_6	-0.76	0.68	0.83	0.30	-0.35
P_2xP_7	1.51**	-0.92	-0.91 *	0.89 *	0.74*
P_2xP_8	-1.05 *	-1.09*	-1.32**	-0.68	-0.55
P_2xP_9	3.84**	1.34*	-0.63	-1.36 **	-0.02
P_2xP_{10}	-0.60	0.93	-0.67	-0.61	-1.66**
P_3xP_4	0.25	0.15	1.15 **	0.30	-0.55
P_3xP_5	2.21 **	-0.42	-0.25	-1.86 **	0.70 *
P_3xP_6	2.03**	-0.21	-0.90 *	-0.55	-0.43
P_3xP_7	0.28	-0.87	1.23 **	0.38	-0.50
P_3xP_8	-0.52	-0.39	0.60	2.09**	0.57
P_3xP_9	-2.33 **	1.10*	-0.89 *	-1.05*	0.17
P_3xP_{10}	1.95 **	-0.88	0.69	0.67	1.39**
P_4xP_5	-1.32*	0.40	-0.35	-1.64**	-1.81**
P_4xP_6	-1.03*	-2.13**	0.00	-0.48	-0.75*
P_4xP_7	-0.36	0.60	-0.41	-0.33	-0.19
P_4xP_8	-1.98 **	-0.39	0.99*	1.91**	0.22
P_4xP_9	0.98	0.98	0.74	0.24	1.40**
P_4xP_{10}	1.23 *	-0.22	-0.96*	-0.76	0.54
P_5xP_6	1.10*	-0.09	-1.21**	-0.27	-0.03
P_5xP_7	0.74	1.94**	-0.76	-1.07*	-0.21
P_5xP_8	-2.74**	-1.89**	1.63 **	0.97*	-0.07
P_5xP_9	0.09	0.46	-0.88 *	-1.96 **	0.16
P_5xP_{10}	-0.99	0.47	1.59**	2.50**	1.15**
P_6xP_7	0.47	0.04	-0.06	-0.42	1.36 **
P_6xP_8	0.91	-1.19*	0.09	-0.38	-0.10
P_6xP_9	0.07	-4.29**	-0.50	0.03	-0.37
P_6xP_{10}	-3.85 **	1.33*	-1.15**	-0.34	0.29
P_7xP_8	-0.31	0.40	-0.04	-0.32	-0.61
P_7xP_9	-0.55	1.11*	1.63 **	1.38**	0.36
P_7xP_{10}	0.91	-2.12**	1.35 **	0.77	-0.35
P_8xP_9	1.50 **	0.93	-1.26 **	-1.47**	-0.20
P_8xP_{10}	-0.47	-1.27 *	-1.05*	-1.71 **	0.02

P_9xP_{10}	-1.94 **	-1.46**	-0.62	-0.44	-1.79 **
S.E. (S_{ij})	1.01	1.02	0.83	0.87	0.66
S.E. (S_{ij}-S_{ik})	1.49	1.50	1.22	1.28	0.97

Table-2.1: Estimation of specific combining ability (SCA) effect of 45 F_1 hybrids for 15 characters of bitter gourd

Hybrids	Sex ratio male: female	Days to first fruit harvest	Vine length (m)	No. of primary branches per plant	Fruit length (cm.)
P_1xP_2	0.06	1.16*	-0.10	4.92**	0.37
P_1xP_3	-0.34	-3.13 **	0.31	-0.69	1.45 **
P_1xP_4	-0.24	-4.47 **	-0.16	-2.02 **	0.83
P_1xP_5	-0.05	-2.50 **	0.23	-0.43	2.78**
P_1xP_6	-0.30	-1.20*	-0.22	-3.95 **	-2.12**
P_1xP_7	-0.43	-3.62 **	0.16	2.51 **	0.08
P_1xP_8	-0.20	-0.62	0.06	-1.72 **	2.29**
P_1xP_9	-0.90**	0.35	0.11	1.92 **	-1.46**
P_1xP_{10}	-1.11 **	3.87 **	-0.41 *	-0.75	1.09 *
P_2xP_3	0.26	-5.44 **	0.38 *	0.48	0.31
P_2xP_4	0.82**	-2.21 **	-0.13	-1.78 **	-1.04*
P_2xP_5	-0.57 *	-1.17*	-0.50 **	-2.59 **	0.47
P_2xP_6	-1.11 **	-0.44	-0.05	-0.97	2.34**
P_2xP_7	0.44	-4.80**	-0.32	-2.68 **	0.27
P_2xP_8	-0.95 **	-0.24	-0.10	1.99**	-0.84
P_2xP_9	-1.28**	-0.09	-0.12	-2.24 **	1.61**
P_2xP_{10}	-0.54 *	-1.94**	-0.09	-3.81**	-1.92**
P_3xP_4	-1.26**	0.06	-0.55 **	0.37	2.57**
P_3xP_5	-0.16	1.20*	0.00	-2.60**	-0.15
P_3xP_6	0.54*	2.53 **	-0.03	1.21*	1.25 *
P_3xP_7	-0.01	1.84**	-0.18	0.50	1.95**
P_3xP_8	0.71**	0.81	-0.10	-0.60	0.17
P_3xP_9	0.64*	-0.38	-0.13	-2.69**	-1.45**
P_3xP_{10}	1.36**	-0.30	0.19	0.94	1.09*
P_4xP_5	1.00**	-0.67	0.26	1.07	0.50
P_4xP_6	-1.05 **	-2.28 **	-0.18	-1.32*	0.00
P_4xP_7	-0.40	0.03	-0.26	-1.03	-0.14
P_4xP_8	-0.89 **	1.06	0.13	-1.16*	-0.19
P_4xP_9	0.89**	-0.06	-0.15	-1.45 **	1.66 **
P_4xP_{10}	1.66**	-3.31 **	0.59**	2.04 **	-0.79
P_5xP_6	0.43	0.53	0.13	1.51 **	0.41
P_5xP_7	-0.51 *	1.31 *	-0.20	-3.84 **	1.68 **
P_5xP_8	-2.75**	-1.79 **	-0.11	-3.10 **	-0.44
P_5xP_9	0.44	0.95	0.11	0.47	-1.06 *
P_5xP_{10}	-1.50 **	-1.10 *	-0.55 **	-2.47 **	-2.05 **
P_6xP_7	-0.77 **	-0.50	0.31	-0.89	-0.15
P_6xP_8	1.67 **	-2.00 **	0.20	0.65	1.86**
P_6xP_9	-0.60*	-0.92	-0.16	-0.38	-1.09*
P_6xP_{10}	0.54 *	0.29	-0.36 *	-2.18**	1.72 **
P_7xP_8	-0.70**	1.31 *	0.02	-0.26	-0.27
P_7xP_9	1.24**	1.59**	0.66**	2.11 **	2.11**
P_7xP_{10}	-0.98 **	-2.13 **	-0.12	-0.56	0.72
P_8xP_9	-1.65**	0.88	-0.10	-0.42	0.33
P_8xP_{10}	0.74 **	-3.40 **	0.04	0.21	1.97 **
P_9xP_{10}	0.30	-2.39**	-0.14	-0.85	0.32
S.E. (S_{ij})	0.49	1.08	0.33	1.08	0.95
S.E. (S_{ij}-S_{ik})	0.72	1.58	0.48	1.59	1.39

Table-2.2: Estimation of specific combining ability (SCA) effect of 45 F_1 hybrids for 15 characters of bitter gourd

Hybrids	Fruit circumference (cm)	Average Fruit Weight (g.)	No. of fruits per plant	Fruit Yield per plant (Kg.)	Number of seeds /fruit
P_1xP_2	0.40	10.88 **	-8.75 **	-0.22 **	1.65 **
P_1xP_3	-0.39	-4.43 **	3.22 *	0.06	3.37 **
P_1xP_4	-0.18	-5.84 **	4.32**	0.08	1.14
P_1xP_5	2.77 **	9.11**	-2.03	0.13	1.69 **
P_1xP_6	-1.23 *	-5.66 **	-1.25	-0.21 **	-6.94 **
P_1xP_7	0.12	0.00	1.86	0.13	-2.70 **
P_1xP_8	1.08 *	9.17 **	2.46	0.42 **	0.63
P_1xP_9	0.14	-8.17 **	0.75	-0.17 *	-3.95**
P_1xP_{10}	0.16	7.59**	-2.79 *	0.02	0.09
P_2xP_3	0.04	3.23 **	-2.34	-0.04	-2.91 **
P_2xP_4	0.52	-2.98 **	2.52	0.08	-0.08
P_2xP_5	-0.60	1.31	-5.00**	-0.24 **	1.21*
P_2xP_6	1.87**	1.77	0.65	0.13	1.44 *
P_2xP_7	0.78	3.19 **	-0.04	0.10	-1.85**
P_2xP_8	-0.85	-2.96 **	3.89 **	0.11	-2.32 **

P_2xP_9	1.20 *	6.02**	0.32	0.21 **	3.50**
P_2xP_{10}	1.42 **	-5.88**	3.45 **	0.04	-2.33**
P_3xP_4	1.46 **	-0.02	-5.10 **	-0.28**	1.61 **
P_3xP_5	-0.86	-4.73 **	3.52 **	0.08	-0.17
P_3xP_6	-0.29	7.26 **	2.23	0.33**	-0.73
P_3xP_7	1.15 *	3.45 **	1.07	0.13	2.44 **
P_3xP_8	0.15	8.12 **	-1.00	0.14	0.51
P_3xP_9	-0.79	-4.36**	-4.17 **	-0.32**	-3.51**
P_3xP_{10}	-1.01 *	9.04 **	-1.64	0.09	0.09
P_4xP_5	-0.28	10.33**	-2.29	0.09	1.60 **
P_4xP_6	-0.04	-5.14 **	-4.05 **	-0.35**	0.96
P_4xP_7	-1.03 *	-0.46	-0.87	-0.06	-1.73 **
P_4xP_8	-0.67	-0.21	1.20	0.06	0.94
P_4xP_9	0.19	5.77 **	-1.18	0.06	4.35 **
P_4xP_{10}	0.81	-1.20	4.48 **	0.24**	-3.61 **
P_5xP_6	0.10	-3.39 **	2.90 *	0.09	-3.88**
P_5xP_7	0.78	4.83 **	-1.45	0.01	-0.37
P_5xP_8	-0.72	-5.53 **	-2.18	-0.26 **	-1.24 *
P_5xP_9	-0.67	1.33	1.71	0.14	-0.62
P_5xP_{10}	-1.18 *	-5.58 **	-5.76 **	-0.42 **	-0.99
P_6xP_7	-0.65	2.42**	-0.67	-0.01	2.59 **
P_6xP_8	0.38	3.87**	3.86**	0.35 **	0.19
P_6xP_9	-0.43	-7.01 **	2.35	-0.04	-3.99**
P_6xP_{10}	0.39	-1.19	0.75	0.00	0.45
P_7xP_8	-1.20 *	-7.38 **	4.04 **	0.03	-0.17
P_7xP_9	0.78	12.88**	1.07	0.33 **	5.25 **
P_7xP_{10}	0.47	4.97 **	-0.07	0.08	-2.85 **
P_8xP_9	0.41	-0.35	-0.60	-0.05	-3.82 **
P_8xP_{10}	1.50**	4.68**	-3.74 **	-0.12	1.22*
P_9xP_{10}	0.02	-4.60 **	0.89	-0.05	1.37 *
S.E. (S_{ij})	0.92	1.78	2.57	0.14	1.18
S.E. (S_{ij}-S_{ik})	1.36	2.62	3.78	0.21	1.74

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