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Utility of gynoecious sex form in heterosis breeding of bitter gourd and genetics of associated vegetative and flowering traits

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ABSTRACT

This is the first report on discovering gene action in bitter gourd using gynoecious line as one parent in experimental design. Gene effects for yield and its contributing traits in bitter gourd were studied by involving 36 cross combinations obtained from crossing 9 diverse bitter gourd lines including one gynoecious line in half-diallel fashion. The ratio between additive and dominance variance revealed the predominance of non-additive gene action for node to first female flower appearance, days to first female flower appearance, days from fruit setting to maturity, sex ratio and yield per plant. However, greater role of additive gene effects than dominance was evident for the characters like vine length. Heterosis over standard check (~Pusa Do Mousami) was also appreciable for all the traits under study. All the hybrids with gynoecious line (~DBGY-201) as one parent were heterotic for earliness as well for vine length in desirable direction. The hybrid, DBGY-201 × Priya was the best performer for yield, DBGY-201 × Arka Harit for sex ratio and NDBT-12 × Priya for days to fruit set from maturity. Highest yield was recorded in the parental line P1 (DBGY-201) followed by P2 (Pusa Do Mousami) and P3 (Pusa Vishesh). Gynoecious line was promising for its future use in heterosis and hybridization programme based on combining ability.

Key words: Gene action, gynoecious, heterosis, *Momordica charantia*.

INTRODUCTION

Momordica charantia L. (syn. bitter gourd, balsam pear, bitter melon, bitter cucumber, and African cucumber; 2n = 22) is a member of the family *cucurbitaceae* and grown throughout tropics (Jeffrey, 12). The original place of domestication of *Momordica charantia* is unknown (Li, 13). However, the areas of Southern China or Eastern India have been proposed as probable centre of origin by Raj *et al.* (15), and Walters and Decker-Walters (21). India is endowed with a wide range of diversity in this crop, hence there is a vast opportunity for genetic improvement (Dey, 5). The consumer's preference for fruit shape, size and colour is region specific. The north Indians prefer long or medium long and spindle shaped glossy green fruits whereas south Indians require long but white fruits. In eastern parts of the country small and dark green-fruited (var. *muricata*) types are preferred. The fruit morphology varies greatly in colour, size and the exocarp characteristics (Dey *et al.*, 8). For instance, Indian *Momordica charantia* var. *charantia* cultivars bear large fusiform fruit, while wild, free living *M. charantia* var. *muricata* ecotypes develop small, round fruits (Chakravarty, 3).

In spite of wide range of diversity, very little work has been undertaken to exploit this naturally endowed diversity in the form of hybrid breeding (Dey, 6). A speedy improvement is possible through heterosis breeding. Hybrids in most of the vegetable crops offer opportunity of earliness, high yield, quality improvement besides better capacity to face biotic and abiotic stresses. Gene action gives an insight into a particular traits and help in deciding breeding method for best possible improvement of a trait. Non-additive gene action for a trait indicates that heterosis breeding would be most fruitful for improvement of this trait.

The predominant sex form in bitter gourd is monoecious, however, gynoecious sex form has been reported in recent past both from India and China (Dey, 5; Ram *et al.*, 16; Ram *et al.*, 17; Zhou *et al.*, 22). The subsequent generations using gynoecious as one parent shows very high percentage of pistillate flowers and have high yield potential (Ram *et al.*, 16). Gynoecious sex inheritance pattern varies in different accessions of cucumber and other cucurbitaceous crops. Moreover, gynoecism in bitter gourd is under the control of a single recessive gene (g*y-1*) (Ram *et al.*, 17; Dey *et al.*, 6). However, there is no serious effort to study the feasibility of gynoecious line in heterosis breeding programme of bitter gourd. This study was conducted to understand the genetic control of various floral and vegetative traits determining yield of this crop. Utility of gynoecious trait in improving various desirable traits of this crop was also studied through diallel fashion.

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MATERIALS AND METHODS

Nine previously established to be genetically diverse inbreds of bitter gourd namely, DBGY-201 (P1; gynoecious line), Pusa Do Mausami (P2) and Pusa Vishesh (P3), PBIG-44-3 (P4), NDBT-12 (P5), Priya (P6), DVBTG-5-5 (P7), Nakhara (P8) and Arka Harit (P9) were taken for the present study. All the lines were hand-pollinated with each other to produce all possible combinations of F_1 hybrids without the reciprocals. In this way a total of 36 [9(9-1/2)] F_1 hybrids were obtained in half-diallel fashion (Griffing, 10). Pollen for crossing was obtained from freshly dehisced anthers. The seeds of 36 F_1 hybrids and the 9 parental lines (total of 45 genotypes) were sown in polythene bags (15 cm × 10 cm) under the polyhouse at the Vegetable Research Farm, IARI, New Delhi on 8th January, 2007 and transplanted on 12th February, 2007 in a randomized complete-block design, which was replicated three times. The seedlings were transplanted on both sides of the channel with a spacing of 2 m between channel and 45 cm between plants with 90 cm irrigation channels. The recommended NPK fertilizer doses and cultural practices along with plant protection measures were followed to raise an ideal crop. The fruits were harvested at marketable stage. Ten plants were selected, after discarding the border plants at both ends, and were examined for 6 quantitative traits: i) vine length ii) node at 1st female flower appearance, iii) days to first female flower appearance iv) days from fruit setting to maturity v) sex ratio (male: female flower) vi) yield per plant (g). The expected values of the components of genetic variation were estimated as suggested by Hayman (11). Heterosis was expressed as percentage increase or decrease of F_1's over standard parent (Pusa Do Mousami) and was calculated by using the formulae, Standared heterosis = $\frac{\overline{F_1}-\overline{SV}}{\overline{SV}} \times 100\%$ as suggested by Fonseca and Patterson (9). Heritability (narrow sense) was calculated by using the formulae, $h_{ns} = \frac{2\sigma^2}{2\sigma^2_g + \sigma^2_s + \sigma^2_e} \times 100$. Where, σ_g^2 = analytical estimate of variance due to GCA, σ_s^2 = analytical estimate of variance due to SCA and σ_e^2 = analytical estimate of variance due to error.

RESULTS AND DISCUSSION

The detailed knowledge about the magnitude and nature of genetic variation in a specific population is of prime importance for the effective prediction of most effective breeding programme (Debnath, 4). The suitability of breeding methods for improvement of particular trait depends upon nature of gene action.

The results of diallel analysis revealed over-dominance for most of the characters namely, node to first female flower, days to first female flower appearance, days from fruit setting to maturity, sex ratio and yield per plant (Table 1). In all the characters except vine length, the dominance component of genetic variation (H_1) was higher than additive component (D). Heritability in narrow sense (h) was found highest (71.37%) in growth related vegetative character, vine length while lowest value was recorded for yield per plant (4.80%). All the other traits like, node to first female flower appearance, days to first female flower appearance, days from fruit set to maturity and sex ratio had narrow sense heritability less than 50 percent, which is indicative of predominance of non-additive gene action for most of the traits under study. The F value was negative for four characters under investigation except vine length and node to first female flower. This indicates predominance of recessive gene in parental lines though dominant genes are not less important as negative F value is indicative of recessive genetic control and positive F value indicates dominant gene control (Hayman, 11). The proportion of genes with positive and negative effect in the parents was found to be less than 0.25 for all the characters under study except days from fruit set to maturity where it was perfectly 0.25. This was indicative of asymmetry at loci showing dominance. The mean degree of dominance was found to be more than one for all the characters under study except vine length. This also confirmed over-dominance for most of the yield related characters under study. These results were in consonance with the report of Shirohi and Choudhary (20), and Matoria and Khandelwal (14). They also revealed the preponderance of non-additive gene action in controlling most of the vegetative and floral characters of bitter gourd. The predominance of non-additive gene action and low to moderate narrow sense heritability for the characters studied suggest that heterosis breeding would be advantageous to get higher gain in bitter gourd. Studies on heterosis also confirmed that hybrid breeding in this crop is highly useful in improving earliness in flowering and enhancing yield.

Earliness in bitter gourd is attributed to node number to first female flower and time required for first female flower appearance. Based on node at first appearance of female flowers, P1 (DBGY-201) was found to be earliest followed by P5 (NDBT-12) and P3 (Pusa Vishesh) (Table 2). Sex ratio determines fruitfulness of most crops in general and cucurbitaceous crops in particular (Robinson and Decker-Walters, 18). The higher the proportion of female flower, the greater is the productivity.

Table 1. Estimation of the genetic components of variation for various vegetative and floral traits.

Component	Vine length	Node to first female flower appearance	Days to first female flower appearance	Days from fruit set to maturity	Sex ratio (male: female)	Yield per plant
D	3220.37** ±231.65	12.40** ±1.45	107.00** ±16.48	1.23* ±0.52	98.94** ±18.51	89216.96 ±12475.69
H_1	1702.63** ±511.30	20.93** ±3.21	177.15** ±36.37	3.51** ±1.14	232.61** ±40.86	1413988.36** ±275359.85
H_2	1069.33* ±439.63	18.64** ±2.76	152.77** ±31.27	3.44** ±0.98	178.43** ±35.13	789957.04** ±236709.58
F	571.00 ±540.40	6.43 ±3.39	-18.00 ±38.45	-0.03 ±1.20	-19.83 ±43.19	-314482.88 ±291033.42
h_2	140.96 ±294.44	0.77 ±1.85	46.34* ±20.95	0.00 ±0.66	123.91** ±23.53	1124859.37** ±158574.19
E	39.93 ±75.25	0.52 ±0.46	8.78 ±5.21	0.11 ±0.16	1.58 ±5.85	9345.17 ±39451.60
$(H_1/D)^{1/2}$	0.73	1.30	1.29	1.69	1.53	3.98
$H_2/4H_1$	0.16	0.22	0.22	0.25	0.19	0.14
$(4DH_1)^{1/2}+F/(4DH_1)^{1/2}-F$ or KD/KR	1.27	1.49	0.88	0.96	0.87	-5.99
h^2/H_2	0.13	0.04	0.30	0.02	0.69	1.42
Heritability (narrow sense)	71.37	42.82	31.72	23.53	27.65	4.80

*, ** Significant at 5 and 1% levels

Lowest sex ratio was found in the gynoecious line, P1 (DBGY-201) followed by P5 (NDBT-12) and P3 (Pusa Vishesh). Dwarf vine is considered as a desirable growth habit in bitter gourd. The shortest vine length was found in parent P3 (Pusa Vishesh) followed by P7 (DVBTG-5-5) and P8 (Nakhara). For higher yielding ability the gynoecious parent (DBGY-201) was excellent performer. The widely cultivated Pusa Do Mousami (P2) and Pusa Vishesh (P3) also proved to be good yielder. All the combinations with gynoecious line as female were proved to be excellent in this respect. Gynoecious parent incorporated in this study holds immense potentiality for utilization in hybrid bitter gourd.

The superiority of the F_1 hybrids (only in desirable direction) was also appreciable in comparison to standard check (Pusa Do Mousami) in 30 crosses for vine length, 25 crosses for node to first female flower, 23 crosses for days to first female flower opening, five crosses for days to fruit set to maturity, 23 crosses for sex ratio and twenty for yield per plant (Table 3). It is important to note that the crosses involving gynoecious line (DBGY-201) as one parent with respect to vine length, sex ratio and yield per plant were outstanding performers. This type of result was also appeared in studies involving gynoecious lines as female parent (Ram *et al.*, 16; Behera *et al.*, 1). Thus, the gynoecious line can be taken in the improvement programme of bitter gourd (hererosis and hybridization) to get more yield and to create population with better sex ratio. Dey *et al.* (7) also reported similar result in bitter gourd.

In studying heterosis it was observed that there is tremendous scope in improving different vegetative and flowering traits by developing F_1 hybrids in this crop. More importantly, gynoecious line, DBGY-201, was proved to be very useful in heterosis breeding as it help developing hybrids with earliness and more fruiting with ease. For vine length, standard heterosis ranged form -36.08 (P1 × P3) to 16.58 (P6 × P8) per cent. Out of 36 crosses, 24 crosses had significant negative heterosis, which was desired. Highest negative heterosis was shown by P1 × P3 having relative heterosis of -36.08% followed by P1 × P7 (-34.01%) and P2 × P3 (-28.08%). Fifteen

Table 2. Mean performance of parents and hybrids for growth and yield related traits.

Line/F_1 hybrid	Vine length (cm)	Node to first female flower appearance	Days to first female flower appearance	Days from fruit set to maturity	Sex ratio (male:female)	Yield per plant (g)
P_1	213.27	7.07	34.72	10.28	0.00	1860.31
P_2	293.8	13.68	60.27	9.54	17.72	1609.77
P_3	178.68	12.91	57.21	11.93	14.71	1418.33
P_4	326.95	14.92	70.88	10.61	27.55	1222.04
P_5	245.68	9.15	54.50	8.83	13.16	937.05
P_6	334.81	13.67	69.92	12.17	29.93	1282.67
P_7	194.00	16.27	65.95	10.66	24.44	1107.74
P_8	212.31	19.25	57.21	11.87	32.15	902.13
P_9	256.63	13.22	58.99	11.61	21.16	1103.76
P1 × P2	213.13	8.37	36.94	9.82	2.83	3608.67
P1 × P3	187.80	8.00	34.54	11.07	2.28	3072.05
P1 × P4	253.81	13.33	51.90	10.29	1.05	2284.27
P1 × P5	225.31	8.75	42.20	9.61	0.30	2914.35
P1 × P6	258.92	12.73	54.24	11.94	0.13	3644.72
P1 × P7	193.87	15.75	66.74	10.75	5.13	3594.42
P1 × P8	209.66	14.00	41.72	11.08	1.61	2153.3
P1 × P9	232.86	10.69	36.31	11.39	0.07	2920.5
P2 × P3	211.30	11.00	46.62	11.09	11.45	2182.64
P2 × P4	298.86	15.79	60.95	10.14	24.47	1777.91
P2 × P5	258.70	12.48	59.52	9.16	12.40	1282.87
P2 × P6	300.37	10.31	43.13	11.91	26.36	1716.11
P2 × P7	225.56	15.04	51.89	10.31	6.91	2352.76
P2 × P8	242.28	11.07	48.03	10.96	30.35	1283.33
P2 × P9	259.86	12.25	49.36	10.80	3.90	2011.86
P3 × P4	258.20	14.90	67.07	11.46	9.04	1615.76
P3 × P5	222.16	6.95	44.29	11.23	20.16	888.76
P3 × P6	280.30	10.13	51.59	13.16	32.89	1010.87
P3 × P7	240.57	10.08	52.00	12.11	6.68	2339.22
P3 × P8	243.49	15.91	55.25	11.58	23.60	927.06
P3 × P9	256.59	14.61	64.86	11.73	3.39	1692.74
P4 × P5	276.25	16.35	70.93	10.84	37.72	1131.36
P4 × P6	334.59	10.21	63.80	11.94	23.45	1256.10
P4 × P7	277.72	15.40	72.94	12.55	11.02	1770.34
P4 × P8	272.24	11.72	53.20	9.46	28.42	931.45
P4 × P9	298.57	14.59	63.56	9.64	14.06	1178.54
P5 × P6	312.16	12.12	64.70	8.02	20.32	1081.28
P5 × P7	255.56	11.90	60.45	8.66	5.08	1868.20
P5 × P8	248.88	14.68	51.02	11.83	20.76	892.38
P5 × P9	262.92	10.98	55.39	11.69	10.46	1403.50
P6 × P7	320.16	18.57	75.01	12.69	14.35	2764.13

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Line/F_1 hybrid	Vine length (cm)	Node to first female flower appearance	Days to first female flower appearance	Days from fruit set to maturity	Sex ratio (male:female)	Yield per plant (g)
P6 × P8	342.50	16.09	61.82	12.33	31.50	1024.01
P6 × P9	333.87	12.69	58.28	12.03	14.58	1257.08
P7 × P8	216.24	17.82	61.77	8.62	9.07	2331.40
P7 × P9	228.92	12.75	55.01	10.80	5.59	2107.48
P8 × P9	223.88	12.50	48.61	11.39	25.93	1015.97
Mean	256.31	12.90	55.67	10.92	15.07	1749.58
CD (at 5%)	17.87	2.02	8.35	0.95	3.88	243.84

Table 3. Heterosis for different vegetative and floral characters in bitter gourd.

Cross	Heterosis over standard check (Pusa Do Mousami)					
	Vine length	Node to first female flower appearance	Days to first female flower appearance	Days from fruit set to maturity	Sex ratio (male:female)	Yield per plant
P1 × P2	-27.46**	-38.82**	-38.71**	2.93	-84.03**	124.17**
P1 × P3	-36.08**	-41.52**	-42.69**	16.03**	-87.13**	90.84**
P1 × P4	-13.61**	-2.56	-13.89*	7.86	-94.07**	41.90**
P1 × P5	-23.31**	-36.04**	-29.98**	0.73	-98.31**	81.04**
P1 × P6	-11.87**	-6.94	-10.00	25.15**	-99.27**	126.41**
P1 × P7	-34.01**	15.13*	10.73	12.68	-71.05**	123.29**
P1 × P8	-28.64**	2.33	-30.78**	16.14**	-90.91**	33.76**
P1 × P9	-20.74**	-21.86**	-39.75**	19.39**	-99.60**	81.42**
P2 × P3	-28.08**	-19.59*	-22.65**	16.24**	-35.38**	35.59**
P2 × P4	1.70	15.42*	1.12	6.28	38.09**	10.44
P2 × P5	-11.95**	-8.77	-1.24	-3.98	-30.02**	-20.31*
P2 × P6	2.23	-24.63**	-28.44**	24.84**	48.75**	6.61
P2 × P7	-23.23**	9.94	-13.90*	8.07	-61.00**	46.16**
P2 × P8	-17.54**	-19.08*	-20.31**	14.88**	71.27**	-20.27*
P2 × P9	-11.55**	-10.45	-18.10*	13.21*	-77.99**	24.98**
P3 × P4	-12.12**	8.91	11.28	20.12**	-48.98**	0.37
P3 × P5	-24.38**	-49.20**	-26.51**	17.71**	13.76	-44.78**
P3 × P6	-4.59	-25.95**	-14.40*	37.95**	85.60**	-37.20
P3 × P7	-18.12**	-26.32**	-13.72	26.93**	-62.30**	45.31**
P3 × P8	-17.12**	16.30*	-8.33	21.38**	33.18**	-42.41**
P3 × P9	-12.67**	7.81	7.61	22.95**	-80.87**	5.15
P4 × P5	-5.97	19.52*	17.68*	13.62*	112.87**	-29.71**
P4 × P6	13.88**	-25.37**	5.85	25.15**	32.33**	-21.97**
P4 × P7	-5.47	12.57	21.02**	31.55**	-37.81**	9.97
P4 × P8	-7.34	-14.33	-11.73	-0.84	60.38**	-42.13**
P4 × P9	1.66	6.65	5.45	1.04	-20.65	-26.78**
P5 × P6	6.24	-11.40	7.35	-15.93**	14.67	-32.83**
P5 × P7	-13.02**	-13.01	0.29	-9.22	-71.33**	16.05*

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Cross	Heterosis over standard check (Pusa Do Mousami)					
	Vine length	Node to first female flower appearance	Days to first female flower appearance	Days from fruit set to maturity	Sex ratio (male:female)	Yield per plant
P5 × P8	-15.29**	7.31	-15.35*	24.00**	17.15	-44.56**
P5 × P9	-10.51**	-19.74**	-8.10	22.53**	-40.97**	-12.81
P6 × P7	8.97*	35.75**	24.46**	33.01**	-19.02	71.71**
P6 × P8	16.58**	17.62*	2.57	29.24**	77.76**	-36.38**
P6 × P9	13.63**	-7.24	-3.30	26.10**	-17.72	-21.91**
P7 × P8	-26.40**	30.26**	2.48	-9.64	-48.81**	44.83**
P7 × P9	-22.08**	-6.80	-8.73	13.20*	-68.45**	30.92**
P8 × P9	-23.80**	-8.63	-19.35**	19.39**	46.33***	-36.88**
Range	-36.08-16.58	-49.20-35.75	-42.69-24.46	-15.93-37.95	-99.60-112.87	-44.79-126.41
CD (at 5%)	17.87	2.02	8.35	0.95	3.88	243.84
CD (at 1%)	23.77	2.68	11.12	1.27	5.16	324.31

*, ** Significant at 5 and 1% levels

crosses showed negative heterosis for days to first female flower appearance and best performing hybrids were P1 × P3 (-42.69), P1 × P9 (-39.75%) and P1 × P2 (-38.71%). In this case it is discernable that the combinations with gynoecious line as one parent were very early with respect to female flower appearance. For node to first female flower standard heterosis ranged from -49.20 (P3 × P5) to 35.75 (P6 × P7) per cent. Besides, P1 × P3 (-41.52%) and P1 × P2 (-38.82%) showed very high standard heterosis in desired direction. In case of duration taken for fruit set to maturity, effect of heterosis was not encouraging as only five crosses revealed heterosis in desired direction but only one cross, P5 × P6 (-15.93%) gave significant value. Sex ratio is also amenable to improvement through heterosis breeding which was evident from the result that 20 crosses showed significant heterosis over the standard check. Range of heterosis was from -99.60 (P1 × P9) to 112.87 (P4 × P5) per cent. The best crosses for this particular character were obtained when one of the parent was gynoecious line, DBGY-201. Sixteen crosses showed significant positive standard heterosis for yield per plant. Standard heterosis ranged from -44.79 (P3 × P5) to 126.41 (P1 × P6) per cent. The best combinations were P1 × P6 followed by P1 × P2 (124.17%), P1 × P7 (123.29%) and P1 × P3 (90.84%). The combinations with outstanding yield performance were obtained by using gynoecious line as female parent in almost all the cases. Potentiality of gynoecious lines in hybrid breeding of bitter gourd have been reported in our earlier studies (Dey *et al.* 7; Behera, 2).

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