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Genetic studies in F_3 generation of bitter gourd (*Momordica charantia* L.)

VK Bahiram, BB Dhakare, DB Khirsagar and VR Joshi

Abstract
The present investigation entitled "Genetic studies in Bitter gourd (*Momordica charantia* L.)" was undertaken during summer and *kharif* 2020-2021 by following generation mean analysis to obtain information on gene effects, heritability and genetic advance for various quantitative characters. Three possible crosses involving four parents (RHRBG-26, RHRBG-24, RHRBG-10 and RHRBG-29) with F_3 generations for each of these crosses were evaluated in randomized block design with two replications during summer 2021 at the All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra).
Fifteen progenies of F_3 generations of three crosses *viz*., RHRBG-26 x RHRBG-24 (C_1: 1 x 2), RHRBG-26 x RHRBG-10 (C_2: 1 x 3) and RHRBG-26 x RHRBG-29 (C_3: 1 x 4) were evaluated for yield and yield contributing characters. This investigation highlighted the magnitude of variability, heritability, genetic advance and correlation coefficient in F_3 generations of bitter gourd.
Wide range of variability was observed in all quantitative characters in three crosses of F_3 generations. Phenotypic coefficient of variation (PCV) was higher than the respective genotypic coefficient of variation (GCV) for all the characters studied in F_3 generations indicating environmental factors influencing their expression to some extent. In F_3 generations in most of the crosses the GCV and PCV were higher for number of branches per vine, node at which male and female flower appeared, weight of fruit, number of fruits per vine, fruit yield per vine, fruit yield per plot and fruit yield per hectare., Which showed greater phenotypic and genotypic variability among the progenies and sensitiveness of the attributes for making further improvement by selection.
High heritability coupled with high genetic advance as percent of mean was observed for most of the characters i.e. number of branches per vine, length of vine, node number at which first female flower appeared, number of male flowers per vine, number of female flowers per vine, sex ratio, length of fruit, diameter of fruit, weight of fruit, number of fruits per vine, fruit yield per vine, fruit yield per plot, fruit yield in most of the crosses of F_3 progenies which indicates preponderance of additive gene action. These characters could be improved by pure line selection or mass selection method.
High heritability combined with low genetic advance was observed for some of the traits for which simple selection would not be rewarding. More the less, they could be utilized as a inbred lines in the hybrid development programme. In such condition selection should be delayed so as to minimize the dominance effect. In all three crosses of F_3 generations significant and positive correlation was observed both at phenotypic and the genotypic level between fruit yield per vine and the yield contributing characters such as length of vine, number of branches per vine, number of fruits per vine, weight of fruit, length of fruit and diameter of fruit. Most of these characters were also positively associated among them.

Keywords: Genetic studies, GCV, PCV, heritability, genetic advance, correlation, bitter gourd

Introduction
Bitter gourd (*Momordica charantia* L.) is one of the most important vegetable grown throughout the tropical and subtropical regions of the world with native of Tropical Africa and Asia. The immature fruits are used afresh as well as in processed forms such as stuffed, pickled, sliced and dehydrated. The fruits are also called as bitter melon or balsam pear and harvested at developmental stages up to seed maturity. Fresh bitter gourd is an excellent source of vitamin-C (84mg/100g) which is one of the powerful natural antioxidant. As a rich source of antioxidants, flavonoids, and other polyphenol compounds, bitter gourd may help to reduce your risks for a number of health issues. It provides very low calories (17 cal per100g) (Chakrabarti, 2001) [1]. The fruits are bitter to taste due to the presence of substance called momordicine. Bitter gourd is also reported to use against diseases like paralysis, indigestion and vomiting pain and diabetes.

Bitter gourd shows a lot of variability in yield and yield contributing characters. For developing suitable cultivar the concrete breeding programme should be planned. For this purpose information regarding the nature of magnitude of genetic variation that exist in the breeding population is necessary. Although, bitter gourd is becoming a commercial crop but relatively less attention has been paid towards the improvement of existing germplasm available in different parts of the country.

In recent years, considerable attention is being paid by different bio-material genetics for measuring the magnitude of the epistatic portion of the genetic variance and its importance in breeding programme.

Transgressive segregation produces hybrid progeny phenotypes that exceed the parental phenotypes. Unlike heterosis, extreme phenotypes caused by transgressive segregation are heritably stable. We examined transgressive phenotypes of flowering time in bitter gourd, and revealed transgressive segregation in F_2 populations derived from a cross between parents. These transgressive phenotypes were maintained and evaluate the F_3 population in the present investigation.

Material and Methods

Parents and Hybrids

1. P_1-RHRBG-26.
2. P_2-RHRBG-24.
3. P_3-Akole BG 4-RHRBG-10.
4. P_4-Phule Green Gold-RHRBG-29.

a) Experimental details

Design and Layout of experiment for Evaluation of F_3 generation

1. No of Progenies: 15.
2. Number of parents: 4.
3. Number of crosses: 3.
4. Number of progenies for each cross: 5.
5. Number of plants/progeny: 15.
6. Number of F_3 plants/replication: 225.
7. No. of replication: Two.
8. Design: Randomized Block Design (RBD).

Observations recorded

Number of branches per vine, length of vine, days to appearance first male flower, days to appearance first female flower, node number at which first male flower appeared, node number at which first female flower appeared, days to 50% flowering, number of male flowers per vine, number of female flowers per vine, sex ratio, days to first picking, days to last picking, length of fruit, diameter of fruit, weight of fruit, number of fruits per vine, fruit yield per vine, fruit yield per plot, fruit yield, downy mildew, powdery mildew and fruit fly.

Statistical analysis

The data will be analyzed by using the appropriate procedure to the Randomized Block design as described by Panse and Sukhatme (1995) [6].

Result and Discussion

1. Genetical parameters of variability, heritability and genetic advance

The degree of genetic variability present in the population determines how successful a breeding programme will be selected fifteen offspring from the three F_3 generation crosses RHRBG-26 x RHRBG-29 (C_3: 1 x 4) were examined for growth, yield and quality attributes for genetic factors. (Tables-1).

1.1 Variability, heritability and genetic advance of cross RHRBG-26 x RHRBG-29 (C_3: 1 x 4) for F_3 generations

All of the bitter gourds traits in the cross RHRBG-26 X RHRBG-29 (C_3: 1 x 4) showed a wide range of variability in F_3 progeny (Table 1). Number of branches per vine from 9.71-13.43. The length of vine at last harvest was ranged from 5.49-6.94 cm, days to appearance first male flower from 51.40-54.73, days to appearance first female flower from 54.23-57.90, node number at which first male flower appeared rom 6.13-8.41, node number at which first female flower appeared from 8.55-13.11, days to 50% flowering from 57.30-61.60, number of male flowers per vine from 172.34-266.53, number of female flowers per vine from 24.10-30.70, sex ratio from 6.98-9.59, days to first picking from 65.40-71.60, days to last picking from 140.33-150.70, length of fruit from 19.32-23.16 cm, diameter of fruit from 3.34-4.25 cm, weight of fruit from 75.43-103.71 g, number of fruits per vine from 21.82-30.04, fruit yield per vine from 1.65-3.11 kg, fruit yield per plot from 8.23-15.56 kg, fruit yield from 109.70-207.45 t/ha.

Higher mean estimations for fruit production per vine, fruit weight, average fruit length and average fruit diameter were found in the current experiment. In the bitter gourd, Rajput (2012) [9] found greater mean values for fruit yield per vine, average fruit weight, and average fruit length. For the average fruit weight in muskmelon and fruit yield per vine, Tarsem and Sanjay (1997) [12] found higher mean estimations. In studies on muskmelon, Torkadi and Musmade (2007) [13] and Mehta *et al.* (2010) [5] found comparable results. High mean values were somewhat efficient in distinguishing the superior sergeants, according to Finker *et al*. (1973) [2].

In all three crosses of the F_3 generations, a wide range of variances were seen for the majority of the characteristics, including growth, yield-contributing, and qualitative features. For the features of bitter gourd, such as the number of fruits per plant, fruit length, and days to flowering, Singh *et al.* (1977) [10] reported a wide range of variability. Pathak (2014) [4] found significant variation in the bitter gourd's features, including the number of fruits produced per plant, fruit weight, fruit length, and days to the first male and female flowers. The features of average production per vine, final vine length at last harvest, and average fruit weight in bitter gourd showed a broad range of variability, according to Rajput (2012) [9]. For the traits of average production per vine, final vine length at last harvest and average fruit weight in muskmelon, Mehta *et al.* (2010) [5] discovered significant variance.

In F_3 progeny in cross (C_3) RHRBG-26 X RHRBG-29 characters like number of branches per vine (98.94 and 22.84), length of vine (90.05 and 16.62), node number at which first female flower appeared (99.49 and 29.73), number of male flowers per vine (98.47 and 27.61), number of female flowers per vine (99.99 and 21.52), sex ratio (97.95 and 18.38), length of fruit (99.70 and 11.07), diameter of fruit (98.98 and 17.50), weight of fruit (99.99 and 24.47), number of fruits per vine (99.60 and 20.20), fruit yield per vine (99.94 and 40.93), fruit yield per plot (99.94 and 40.93), fruit yield

(99.94 and 40.93). While it was noted that there were strong estimates of heritability and moderate estimates of genetic advance as a percentage of mean in days to appearance first male flower (76.90 and 3.02), days to appearance first female flower (76.79 and 3.49), node number at which first male flower appeared (79.99 and 14.54). High heritability estimates and smaller genetic advance estimates expressed as a percentage of the mean were found in days to 50% flowering (90.78 and 3.90), days to first picking (97.47 and 5.98), days to last picking (97.50 and 5.50) indicated low estimates of genetic advance as a percentage of the mean in the F_3 progeny and high estimates of heritability.

The variables with high heritability estimates and high genetic advance estimates as a percentage of mean may be caused by the predominance of additive gene effects. Therefore, it would seem that choosing the characters from the crosses above and their corresponding generation would be successful.

Characteristics such as the number of branches per vine, the weight of the fruit, and the yield per vine in bitter gourd were found to have strong heritability together with high genetic advance as measured by the percent mean (Mangal *et al.*, 1983) [4]. For the traits number of primary branches per vine, number of female flowers per vine, sex ratio, average yield per vine, and number of fruits per vine in bitter gourd, Rajput (2012) [9] found high heritability with high genetic advance. In the bitter gourd, Pathak (2014) [4] found strong heritability and significant genetic advance for fruit weight, fruit length and fruit production per plant.

The presence of a non-additive gene effect is indicated by the larger heritability estimate with little genetic advance expressed as a percent mean. Selection may not be successful for certain qualities as a result. Low phenotypic variation in these qualities may be the cause of the high heritability and low genetic advance. Similar findings were recorded by Srivastava and Srivastava (1976) [11] for character days to first flowering, fruit length, and total fruit production. Singh *et al.* (1977) [10] reported that character fruit diameter had a high heritability and a low genetic advance. Similar findings for bitter gourd character days to first flowers and total fruit yield per vine were also reported by Mangal *et al.* (1983) [4]. Pathak (2014) [4] showed minimum genetic advance and strong heritability for character days to the first male and female flowers, which suggested non-additive gene effects in bitter gourd.

Table 1: Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F_3 population of cross RHRBG-26 X RHRBG-29 (C_3: 1 x 4)

Sr. No.	Character	Mean		Range	GCV (%)	PCV (%)	ECV (%)	h^2bs (%)	GA	GAM (%)
		Parents	F_3 Progeny's							
1.	No. of Branches / Vine	10.24	12.02	9.71-13.43	11.15	11.21	1.23	98.94	2.6	22.84
2.	Length of Vine (m)	6.22	6.08	5.49-6.94	8.15	8.96	2.84	90.05	1.0	16.62
3.	Days to Appearance First Male Flower	53.55	52.52	51.40-54.73	1.68	1.91	0.91	76.90	1.6	3.02
4.	Days to Appearance First Female Flower	57.43	55.61	54.23-57.90	1.94	2.21	1.06	76.79	2.0	3.49
5.	Node Number at Which First Male Flower Appeared	8.10	6.88	6.13-8.41	7.89	8.83	4.03	79.99	1.2	14.54
6.	Node Number at Which First Female Flower Appeared	11.91	9.71	8.55-13.11	14.47	14.51	0.97	99.49	3.1	29.73
7.	Days to 50% Flowering	60.70	58.76	57.30-61.60	1.99	2.09	0.64	90.78	2.3	3.90
8.	Number of Male Flowers per vine	172.24	227.62	172.34-266.53	13.51	13.60	1.68	98.47	62.84	27.61
9.	Number of Female Flowers per vine	24.60	26.83	24.10-30.70	10.44	10.45	0.00	99.99	5.77	21.52
10.	sex ratio	7.84	8.74	6.98-9.59	9.02	9.12	1.18	97.95	1.6	18.38
11.	Days to First Picking	69.78	66.96	65.40-71.60	2.95	2.98	0.47	97.47	4.0	5.98
12.	Days to Last Picking	144.85	146.99	140.33-150.70	2.71	2.75	0.44	97.50	8.0	5.50
13.	Length of Fruit (cm)	20.00	21.72	19.32-23.16	5.39	5.40	0.01	99.70	2.3	11.07
14.	Diameter of Fruit (cm)	3.52	3.87	3.34-4.25	8.55	8.59	0.01	98.98	0.7	17.50
15.	Weight of Fruit (g)	79.17	101.77	75.43-103.71	11.88	11.89	0.15	99.99	23.3	24.47
16.	No. Fruits/vine	23.43	27.68	21.82-30.04	9.83	9.85	0.66	99.60	5.3	20.20
17.	Fruit Yield/Vine (kg)	1.86	2.82	1.65-3.11	19.88	19.89	0.01	99.94	1.0	40.93
18.	Fruit Yield/Plot (kg)	9.30	14.09	8.23-15.56	19.88	19.89	0.01	99.94	5.2	40.93
19.	Fruit Yield (q/ha)	124.01	187.82	109.70-207.45	19.88	19.89	0.55	99.94	69.4	40.93

Correlation coefficient of cross RHRBG-26 x RHRBG-29 (C_3: 1 x 4) in F_3 generations

Table 2 shows the results of the association study conducted on 15 F_3 progenies to determine the correlation between yield and yield-contributing characters in F_3 progeny.

The number of branches per vine, length of vine, node number at which male and female flowers appeared, weight of fruit, yield per vine, fruit yield per vine, fruit yield per plot and yield tonnes per hectare all showed high values of genotypic and phenotypic coefficients of variation in the cross RHRBG-26 X RHRBG-29 (C_3: 1 x 4) progeny. The ratio of male to female flowers per vine and the number of male and female flowers per vine showed low levels of genotypic and phenotypic coefficients of variation. Only in the F_3 progeny did the remaining traits, such as days to the first male and female flowers, days to 50% flowering, and days needed for the first and last fruit harvest, record low genotypic and phenotypic coefficients of variation.

Due to the lack of diversity within segregating populations i.e., the opportunity for improvement through selection characters with higher estimates of GCV and PCV might be fully utilized in subsequent selection programmes. Characters with lower estimations of GCV and PCV would be the least used in subsequent selection programmes due to the lack of improvement potential through selection and the minimal amount of variance seen within segregating populations.

These results were consistent with Indresh (1982) [3] high estimations of the GCV for bitter gourd fruit weight, yield per vine, fruit diameter, and fruit length. High GCV average fruit yield per vine, number of branches per vine, average fruit

weight and average number of fruits per vine were found by Mangal *et al.* in (1983) [4]. The shortest GCV was noted for the duration to the bitter gourd's first flower. The number of female flowers per plant, the weight of the fruit and the number of primary branches per plant in bitter gourd were found to have the highest PCV and GCV, according to Raja *et al.* (2007) [8]. In the F_2 and F_3 progeny of bitter gourd, Rajput (2012) [9] observed high GCV and PCV for the number of primary branches per vine, the number of female flowers per vine, the sex ratio, the number of fruits per vine, the fruit yield per vine, the average yield per vine, the average weight of the fruit and the thickness of the fruit flesh. According to Pathak (2014) [4], low GCV and PCV were found for the days to the first male and female bitter gourd flowers, whereas high GCV and PCV were found for the number of fruits per vine, fruit weight, and fruit length.

Table 2: Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F_3 generation of cross RHRBG-26 X RHRBG-29 (C_1: 1 x 4)

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10
1.	No. of Branches/Vine	G	1.000	-0.532**	-0.013	-0.342	-0.275	-0.789**	-0.356	0.133	-0.349	0.670**
		P	1.000	-0.512*	0.003	-0.305	-0.248	-0.786**	-0.352	0.142	-0.347	0.671**
2.	Length of Vine (m)	G		1.000	-0.554**	-0.389*	-0.090	0.239	-0.268	-0.398*	0.138	-0.822**
		P		1.000	-0.414*	-0.296	-0.069	0.245	-0.185	-0.391*	0.131	-0.780**
3.	Days to Appearance First Male Flower	G			1.000	0.881**	0.762**	0.578**	0.785**	-0.476*	-0.660**	0.037
		P			1.000	0.841**	0.551**	0.512*	0.736**	-0.421*	-0.579**	0.061
4.	Days to Appearance First Female Flower	G				1.000	0.802**	0.743**	0.943**	-0.487*	-0.586**	-0.078
		P				1.000	0.622**	0.662**	0.896**	-0.437*	-0.513*	-0.046
5.	Node Number at Which First Male Flower Appeared	G					1.000	0.415*	0.753**	-0.669**	-0.548**	-0.390*
		P					1.000	0.375	0.609**	-0.591**	-0.490*	-0.345
6.	Node Number at Which First Female Flower Appeared	G						1.000	0.711**	-0.415*	-0.110	-0.544**
		P						1.000	0.693**	-0.413*	-0.110	-0.537**
7.	Days to 50% Flowering	G							1.000	-0.566**	-0.530**	-0.276
		P							1.000	-0.555**	-0.505*	-0.263
8.	Number of Male flowers per vine	G								1.000	0.793**	0.617**
		P								1.000	0.787**	0.620**
9.	Number of Female flowers per vine	G									1.000	0.007
		P									1.000	0.007
10.	sex ratio	G										1.000
		P										1.000
11.	Days to First Picking	G										
		P										
12.	Days to Last Picking	G										
		P										
13.	Length of Fruit (cm)	G										
		P										
14.	Diameter of Fruit (cm)	G										
		P										
15.	Weight of Fruit (g)	G										
		P										
16.	No. Fruits/vine	G										
		P										
17.	Fruit Yield/Vine (kg)	G										
		P										
18.	Fruit Yield/Plot(kg)	G										
		P										
19.	Fruit Yield (q/ha)	G										
		P										

S: Symbol, G: Genotypic, P: Phenotypic *, **: Significance at 5% and 1%, respectively.

Sr. No.	Character		11	12	13	14	15	16	17	18	19
1.	No. of Branches / Vine	G	4.907*	-0.169	0.657**	0.669**	0.610**	0.745**	0.712**	0.713**	0.713**
		P	-0.896**	-0.162	0.649**	0.667**	0.607**	0.739**	0.708**	0.709**	0.708**
2.	Length of Vine (m)	G	0.732**	0.779**	0.125	-0.663**	0.019	-0.194	-0.109	-0.109	-0.109
		P	0.726**	0.683**	0.126	-0.609**	0.019	-0.168	-0.096	-0.096	-0.096
3.	Days to Appearance First Male Flower	G	0.100	-0.705**	-0.473*	0.092	-0.585**	-0.137	-0.386	-0.386	-0.386
		P	0.068	-0.634**	-0.401*	0.089	-0.509*	-0.121	-0.338	-0.337	-0.338
4.	Days to Appearance First Female Flower	G	0.370	-0.603**	-0.632**	0.078	-0.815**	-0.400*	-0.630**	-0.632**	-0.632**
		P	0.293	-0.543**	-0.530**	0.055	-0.711**	-0.352	-0.552**	-0.554**	-0.554**
5.	Node Number at Which First Male Flower Appeared	G	0.370	-0.500*	-0.635**	-0.437*	-0.945**	-0.690**	-0.851**	-0.851**	-0.851**
		P	0.352	-0.448*	-0.571**	-0.390*	-0.850**	-0.608**	-0.761**	-0.760**	-0.760**
6.	Node Number at Which First Female Flower Appeared	G	0.807**	-0.065	-0.585**	-0.386	-0.619**	-0.457*	-0.577**	-0.578**	-0.578**
		P	0.801**	-0.075	-0.580**	-0.379	-0.617**	-0.452*	-0.574**	-0.575**	-0.575**
7.	Days to 50% Flowering	G	0.389**	-0.263	-0.427*	0.012	-0.743**	-0.324	-0.555**	-0.556**	-0.556**

		P	0.370	-0.282	-0.390*	0.014	-0.705**	-0.304	-0.525**	-0.527	-0.527
8.	Number of Male flowers per vine	G	-0.507**	-0.156	-0.052	0.253	0.415*	0.070	0.270	0.270	0.270
		P	-0.502**	-0.147	-0.055	0.254	0.411*	0.070	0.267	0.267	0.267
9.	Number of Female flowers per vine	G	0.024	0.234	-0.200	-0.307	0.208	-0.257	-0.021	-0.020	-0.019
		P	0.024	0.231	-0.199	-0.306	0.208	-0.256	-0.021	-0.020	-0.019
10.	sex ratio	G	-0.855**	-0.550**	0.171	0.805**	0.417*	0.444*	0.470*	0.469*	0.469*
		P	-0.844**	-0.537**	0.169	0.798**	0.412*	0.439*	0.464*	0.464*	0.464*
11.	Days to First Picking	G	1.000	0.303	-0.463*	-0.723**	-0.567**	-0.603**	-0.625**	-0.626**	-0.626**
		P	1.000	0.278	-0.457*	-0.702**	-0.560**	-0.585**	-0.613**	-0.614**	-0.614**
12.	Days to Last Picking	G		1.000	0.612**	-0.180	0.440*	0.298	0.373	0.373	0.374
		P		1.000	0.599**	-0.187	0.434*	0.286	0.365	0.365	0.365
13.	Length of Fruit (cm)	G			1.000	0.517*	0.830**	0.887**	0.891**	0.891**	0.891**
		P			1.000	0.512*	0.829**	0.884**	0.890**	0.890**	0.890**
14.	Diameter of Fruit (cm)	G				1.000	0.498*	0.723**	0.653**	0.651**	0.651**
		P				1.000	0.494*	0.721**	0.651**	0.649**	0.649**
15.	Weight of Fruit (g)	G					1.000	0.860**	0.964**	0.965**	0.965**
		P					1.000	0.858**	0.964**	0.964**	0.964**
16.	No. Fruits/vine	G						1.000	0.963**	0.963**	0.962**
		P						1.000	0.962**	0.962**	0.962**
17.	Fruit Yield/Vine (kg)	G							1.000	1.000**	1.000**
		P							1.000	1.000**	1.000**
18.	Fruit Yield/Plot(kg)	G								1.000	1.000**
		P								1.000	1.000**
19.	Fruit Yield (q/ha)	G									1.000
		P									1.000

S: Symbol, G: Genotypic, P: Phenotypic *, **: Significance at 5% and 1%, respectively.

Conclusion

1. The number of branches per vine, length of vine, number of male flowers per vine, number of female flowers per vine, sex ratio, length of fruit, diameter of fruit, weight of fruit, number of fruits per vine, fruit yield per vine, fruit yield per plot, and fruit yield are all highest in F3 of the cross 3 RHRBG-26 X RHRBG-29.
2. All three crossings showed greater broad sense heritability estimates for all characteristics in the summer, although cross 3 (RHRBG-26 x RHRBG-29) consistently showed higher broad sense heritability estimates for the majority of characters in F_3 progenies. The heritability (broad sense) and genetic advance estimates were high for all the characters.
3. Fruit yield per vine and yield-contributing traits including length of vines, number of branches per vine, number of fruits per vine, weight of fruit, length of fruit, and diameter of fruit were found to be significantly and highly positively correlated in cases of F_3 generations of all three crossings. The factors that were substantially and adversely connected with average yield per vine were those like days necessary for first female flower appearance, node at which first female flower appeared, days required for first fruit harvest, and crop length. The majority of these traits were also discovered to have favorable relationships with one another.

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