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AN Alekar
Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, India

KG Shinde
Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, India

MB Khamkar
Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, India

Correspondence
AN Alekar
Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, India

Studies on genetic variability, heritability, genetic advance and correlation in bitter gourd (*Momordica charantia* L.)

AN Alekar, KG Shinde and MB Khamkar

Abstract
A field experiment was conducted at All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during the Summer season in the year 2015. The present investigation was undertaken with 7 progenies with their 20 plants of each progeny for a cross Phule Green Gold x Hirkani and Hirkani x Phule Ujwala of bitter gourd in F_4 generation for evaluating their genetic components such as variability, heritability, genetic advance, genetic advance as a per cent mean and correlation for growth, yield and yield attributes. Significant difference among the progenies was observed for all the traits under study. High value of genotypic and phenotypic coefficient of variability and heritability estimates were associated with greater values of genetic advance as a percent mean were observed for vine length at last harvest, number of primary branches per vine, number of fruits per vine, average fruit yield per vine, average weight of fruit, Average length of fruit, yield tonnes per hectare. Correlation studies revealed that fruit yield per hectare showed highly significant positive correlation with yield and yield contributing characters It is suggested that characters viz., number of female flower per vine, number of fruits per vine, average weight of fruit, crop duration, average length of fruit and average diameter of fruit should be given priority for selecting high yielding genotypes.

Keywords: Variability, heritability, correlation, bitter gourd, genetic advance, F_4 generation

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. It is extensively cultivated throughout the country under two situations i.e. rainy season (July to August) and summer season (January to March) Chakravatry (1959) [3]. The fruits are bitter to taste due to the presence of substance called cucurbitacin. Bitter gourd is also reported to use against diseases like paralysis, indigestion and vomiting pain and diabetes. As the area and production of bitter gourd are increasing fast but the crop is still remained less explored on aspects of crop improvement by breeding methods. Thus, there is much need of cultivars with early fruiting, high yield, and high female to male sex ratio, thick fruits suitable for stuffing, resistance to fruit flies, red pumpkin beetle, mosaic virus, downy and powdery mildew. Therefore, to introgress these horticultural traits, the F_4 progenies were assessed for variability, heritability, genetic advance and correlation for the utilization in crop improvement.

Material and Methods
The experiment was laid out at the All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra). The experimental material consisted of five F_3 progenies from each cross Phule Green Gold x Hirkani and Hirkani x Phule Ujwala along with their parents were sown during summer 2015 and evaluated for F_4 generation. A total of 13 genotypes (10 progenies + 3 parents) were developed from a hybrid and their respective parents and evaluated for F_5 generation. The F_4 generations were evaluated in randomized block design with three replications. Plants of each F_4 progeny were maintained with a plant spacing of 1.5 x 1 m. The Observations were recorded on various growth and yield parameters for F_4 generation. Estimation of variations and genetic advance was done following Johnson *et al.*, (1955), coefficient of variations following Burton and De Vane (1953) and heritability following (Lush, 1949) [11]. The correlation coefficient was estimated as suggested by Snedecor and Cochran (1967) [17].

Result and Discussion

The analysis of variance for 12 characters (Table 1, 2) of bitter gourd revealed sufficient variability among the F_4 progenies. So, there is a scope for considerable improvement in the crop through the characters studies such as Final vine length at last harvest (cm), days required for appearance of first female flower, days required for first harvest of fruit, average weight of fruit (g) fruit yield per hectare, number of fruits per vine, average fruit yield per vine, average length of fruit and crop duration. Similar to the present findings, significant differences for various characters was reported by Rajput (2012) [16], Gupta *et al.,* (2013), Yadav *et al.,* (2012) [19], Pathak *et al.,* (2014) [14] and Singh *et al.,* (2017) [18] in bitter gourd.

Genotypic and phenotypic co-efficient of variation

The coefficient of genotypic and phenotypic variability is helpful to measure the extent of variability present in particular trait. They also provide a measure to compare the variability present among various quantitative traits. The estimates of coefficient of variability revealed that in general magnitude of phenotypic coefficient of variation for all the traits were higher than the magnitude of genotypic coefficient of variation (Table 1, 2). The estimates of phenotypic as well as genotypic coefficient of variation in the cross Phule Green Gold x Hirkani were observed higher for number of primary branches per vine (10.97 and 9.64%), number of fruits per vine (15.81 and 15.08%), average fruit yield per vine (21.47 and 20.90%), average length of fruit (10.05 and 8.54%) and fruit Yield tonnes per hectare (21.48 and 20.92%) which suggest greater variability among the attributes for further improvement by selection. In respect to days to first female flower appearance the close association of GCV (4.79%) and PCV (5.31%). were observed with certain presence of environmental factor ECV (2.29%) in F_4 generation. Whereas, in the cross Hirkani x Phule Ujwala same trade was observedin F_4 generation. Similar results were in agreement with the findings of Raja *et al.* (2007) [15], Rajput (2012) [16] and Pathak (2014) [14] in bitter gourd.

Heritability and Genetic advance as per cent of mean

High value of heritability suggests that selection based on phenotypic expression could be considered as a playing a major role in genetic constitution for the expression of horticulture characters. Heritability (broad sense) was found higher for all of the traits in cross Phule Green Gold x Hirkani and Hirkani x Phule Ujwala for all F_4 progenies are shown in Table 1, 2. Heritability ranges from 72.25 to 94.79 per cent in the cross Phule Green Gold x Hirkani and 66.06 to 97.30 per cent in the cross Hirkani x Phule Ujwala observed in F_4 generation.

The estimates of heritability in broad sense (h^2bs) for the cross Phule Green Gold x Hirkani and Hirkani x Phule Ujwala in F_4 generation were 87.70, 77.14 percent (vine length), 77.13, 77.55 per cent (Number of primary branches per vine), 74.68, 73.69 percent (Node at which first female flower appeared), 72.78, 66.06 percent (Days required for first harvest of fruit), 88.02, 87.61 percent (Crop duration), 90.98, 75.36, percent (Number of fruits per vine), 94.79, 81.26 percent (Fruit yield per vine (kg)), 94.59, 88.11 percent (Average weight of fruit (g)) (Table 1, 2). Above information suggests that, selection based on phenotypic expression could be relied upon as major role of genetic constitution in the expression of these characters. Similar results were reported by Mangal *et al.* (1983) [13], Chaudhari *et al.,* (1988), Islam et al. (2009) [8], Rajput (2012) [16] and Pathak (2014) [14] in bitter gourd and in muskmelon Mali (2015) [12].

The genetic advance for cross Phule Green Gold x Hirkani and Hirkani x Phule Ujwala in F_4 generation (Table 1, 2) ranged from 0.37 to 21.79 and 0.24 to 16.79 respectively. In cross Phule Green Gold x Hirkani the characters like number of fruits per vine (90.98 and 29.63%), fruit yield per vine (94.79 and 41.94%), fruit yield per hectare (94.81 and 41.96%) recorded high estimates of heritability along with high estimates of genetic advance as per cent of mean. Whereas the characters number of primary branches per vine (77.13 and 17.44%), node at which first female flower appeared (74.68 and 11.55%), average weight of fruit (94.59 and 21.10 %), average length of fruit (72.25 and 14.96%), crop duration (88.06 and 14.75%) recorded high estimate of heritability with moderate estimate of genetic advance as per cent of mean. Same pattern was observed in Hirkani x Phule Ujwala in F_4 generation.

In the cross Hirkani x Phule Ujwala for F_4 generation the characters like number of number of fruits per vine (75.36 and 35.24%), fruit yield per vine (81.26 and 35.26%), yield per hectare (81.31 and 35.28%) recorded high estimates of heritability along with high estimates of genetic advance as per cent of mean. Whereas the characters primary branches per vine (77.55 and 21.65%), node at which first female flower appeared (73.69 and 12.05%) and average length of fruit (75.96 and 18.14%) recorded high estimate of heritability with moderate estimate of genetic advance as per cent of mean (Table 1, 2). The traits which exhibited high estimates of heritability along with high estimates of genetic advance as per cent of mean might be due to predominance of additive gene effects. Therefore it appears that selection for characters mentioned in above crosses and their respective generation would be effective. Similar type of results reported in bitter gourd by Mangal *et al.,* (1983) [13], Raja *et al.,* (2007) [15], Rajput (2012) [16], Pathak (2014) [14].

Correlation coefficient

The significant and high positive correlation in F_4 generations both at phenotypic and the genotypic level (Table 3, 4) were observed between fruit yield per vine and the yield contributing characters such as final vine length at last harvest, number of primary branches per vine, number of fruits per vine, average weight of fruit, average length of fruit and average diameter of fruit. While, the characters like days required for first female flower appearance, node at which first female flower appeared and days required for first harvest of fruit and crop duration were significantly and negatively correlated with average yield per vine, which were helpful relationships. Most of these characters were also found to be positively associated among them.

These findings in F_4 generations indicate that the ideal vine should have more vine length, more number of primary branches per vine, more number of fruits per vine, more weight of fruit, more length of fruit and more diameter of fruit and less days required for first female flower appearance, lower node position at which first female flower appeared and less days required for first harvest of fruit. The selection of a better yielder should also emphasis for improvement in these components. Khattra *et al.* (1994) [10], Dey *et al.* (2005) [5], Botau *et al.* (2010) [2], Pathak (2014) [14], Gupta *et al.* (2015) [6] in bitter gourd reported similar trend of correlation coefficient.

Table 1: Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F_4 population of cross Phule Green Gold X Hirkani.

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h^2 bs (%)	GA	GAM (%)
1.	Final vine length at last harvest (cm)	464.36	453.68- 474.15	1.80	1.92	0.67	87.70	2.09	3.48
2.	Number of primary branches per vine	12.37	10.46- 13.53	9.64	10.97	5.24	77.13	2.15	17.44
3.	Days required for appearance of first female flower	56.15	51.70- 60.68	4.79	5.31	2.29	81.40	5.00	8.90
4.	Node at which first female flower appeared	25.49	22.46- 28.79	6.49	7.51	3.78	74.68	2.94	11.55
5.	Days required for first harvest of fruit	61.75	58.13- 66.16	4.02	4.71	2.46	72.78	4.36	7.07
6.	Crop duration (days)	147.71	135.75- 153.48	7.63	8.13	2.81	88.02	21.79	14.75
7.	Number of fruits per vine	42.37	31.93- 50.15	15.08	15.81	4.74	90.98	12.55	29.63
8.	Average fruit yield per vine (kg)	2.64	1.96- 3.57	20.90	21.47	4.88	94.79	1.11	41.94
9.	Average weight of fruit(g)	62.18	56.79- 71.30	10.53	10.82	2.51	94.59	13.12	21.10
10	Average length of fruit (cm)	20.81	18.55- 23.57	8.54	10.05	5.59	72.25	3.11	14.96
11	Average diameter of fruit (cm)	3.48	3.03- 3.66	5.80	6.45	2.82	80.86	0.37	10.74
12	Fruit yield t/ ha	17.64	14.87- 23.78	20.92	21.48	4.89	94.81	7.40	41.96

Table 2: Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F_4 population of cross Hirkani X Phule Ujwala.

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h^2 bs (%)	GA	GAM (%)
1.	Final vine length at last harvest (cm)	466.46	437.37- 493.17	4.33	4.94	2.36	77.14	5.12	7.85
2.	Number of primary branches per vine	12.99	10.26- 13.04	11.93	13.55	6.42	77.55	2.81	21.65
3.	Days required for appearance of first female flower	55.11	50.79- 57.19	4.98	5.87	3.10	72.02	4.80	8.71
4.	Node at which first female flower appeared	24.15	22.10- 26.84	6.81	7.94	4.07	73.69	2.91	12.05
5.	Days required for first harvest of fruit	60.89	57.55- 63.20	4.14	5.10	2.97	66.06	4.23	6.94
6.	Crop duration (days)	147.93	133.86- 161.24	5.88	6.28	2.21	87.61	16.79	11.35
7.	Number of fruits per vine	35.77	29.68- 40.45	18.03	20.76	10.30	75.36	11.53	35.24
8.	Average fruit yield per vine (kg)	2.17	1.62- 2.72	18.99	21.06	9.12	81.26	0.76	35.26
9.	Average weight of fruit (g)	61.19	52.06- 67.48	10.28	10.95	3.77	88.11	12.17	19.88
10	Average length of fruit(cm)	19.32	17.26- 21.88	10.10	11.59	5.68	75.96	3.50	18.14
11	Average diameter of fruit (cm)	3.51	3.28- 3.70	3.48	3.53	0.58	97.30	0.24	7.09
12	Fruit Yield t/ ha	14.50	11.30 - 18.15	18.99	21.06	9.10	81.31	5.11	35.28

Table 3: Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F_4 generation of cross Phule Green Gold X Hirkani (C_1: 1 x 2).

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length at last harvest (cm)	G	1.000	-0.394	0.630**	-0.145	0.672**	0.521*	0.305	-0.000	0.203	0.160	0.211	0.203
		P	1.000	-0.358	0.474*	-0.149	0.475*	0.460*	0.289	-0.026	0.184	0.162	0.246	0.184
2	Number of primary branches	G	-	1.000	0.080	0.789**	-0.045	-0.171	0.110	0.702**	0.446*	-0.756**	-0.236	0.445*
		P		1.000	0.086	0.498 *	-0.022	-0.158	0.090	0.621**	0.384	-0.564**	-0.202	0.382
3	Days required for appearance of first female flower	G	-	-	1.000	0.517*	0.991**	0.602**	0.845**	0.458*	-0.828**	-0.358	-0.819**	-0.828**
		P			1.000	0.288	0.967 **	0.502*	0.677**	0.704**	-0.308	-0.695**	-0.384	-0.704**
4	Node at which first female flower appeared	G	-	-	-	1.000	0.498*	-0.160	0.026	0.757**	-0.413	-0.721**	-0.192	-0.410
		P				1.000	0.217	-0.073	0.066	0.662**	-0.397	-0.522*	-0.089	-0.396
5	Days required for first harvest of fruit	G	-	-	-	-	1.000	0.639**	0.815**	0.455*	0.810**	-0.226	-0.881**	-0.810**
		P					1.000	0.531 *	0.591**	0.388	0.629**	-0.228	-0.748**	-0.629**
6	Crop durations (days)	G	-	-	-	-	-	1.000	0.724**	0.459*	0.750**	-0.217	0.634**	0.751**
		P						1.000	0.616**	0.438*	0.676 **	-0.281	0.599**	0.677**
7	Number of fruits per vine	G	-	-	-	-	-	-	1.000	0.308	0.859**	0.218	0.801**	0.861**
		P							1.000	0.283	0.857**	0.113	0.690**	0.859**
8	Average weight of fruit (g)	G	-	-	-	-	-	-	-	1.000	0.749**	0.773**	0.277	0.747**
		P								1.000	0.734 **	0.645**	0.258	0.732**
9	Average fruit yield per vine (kg)	G	-	-	-	-	-	-	-	-	1.000	0.535*	0.717**	0.986**
		P									1.000	0.639**	0.374	0.975**
10	Average length of fruit (cm)	G	-	-	-	-	-	-	-	-	-	1.000	0.187	0.534*
		P										1.000	0.058	0.407
11	Average diameter of fruit (cm)	G	-	-	-	-	-	-	-	-	-	-	1.000	0.718**
		P											1.000	0.640**
12	Fruit yield t/ ha	G	-	-	-	-	-	-	-	-	-	-	-	1.000
		P												1.000

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

Table 4: Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F_4 generation of cross Hirkani X Phule Ujwala

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length at last harvest (cm)	G	1.000	0.197	0.126	-0.094	0.238	-0.508*	0.079	-0.300	-0.034	-0.617**	-0.684**	-0.034
		P	1.000	0.088	-0.006	-0.049	0.043	-0.458 *	0.228	-0.293	0.101	-0.478 *	-0.567**	0.101
2	Number Of primary branches	G	-	1.000	-0.106	0.201	-0.066	-0.015	0.699**	0.161	0.833**	0.593**	-0.292	0.832**
		P		1.000	-0.031	0.244	0.034	-0.081	0.543 *	0.126	0.663 **	0.419	-0.313	0.664**
3	Days required for appearance of first female flower	G	-	-	1.000	-0.617**	0.978**	-0.196	-0.483*	0.461*	-0.227	-0.275	-0.780**	-0.227
		P			1.000	-0.574**	0.983**	-0.093	-0.394	0.297	-0.245	-0.114	-0.681**	-0.245
4	Node at which first female flower appeared	G	-	-	-	1.000	-0.627**	0.547*	0.785**	0.051	0.787**	0.553**	0.589**	0.786**
		P				1.000	-0.530 *	0.347	0.592**	0.128	0.659**	0.353	0.472 *	0.659**
5	Days required for first harvest of fruit	G	-	-	-	-	1.000	-0.197	-0.453*	0.467*	-0.192	-0.338	-0.854**	-0.193
		P					1.000	-0.100	-0.373	0.315	-0.214	-0.123	-0.720**	-0.215
6	Crop durations (days)	G	-	-	-	-	-	1.000	-0.052	0.762**	0.273	0.153	0.423	0.272
		P						1.000	-0.103	0.687**	0.174	0.214	0.407	0.173
7	Number of fruits per vine	G	-	-	-	-	-	-	1.000	-0.305	0.880**	0.578**	0.199	0.881**
		P							1.000	-0.312	0.889**	0.444 *	0.164	0.889**
8	Average weight of fruit (gm)	G	-	-	-	-	-	-		1.000	0.179	0.195	-0.176	0.177
		P								1.000	0.146	0.211	-0.152	0.145
9	Average fruit yield per vine (kg)	G	-	-	-	-	-	-	-	-	1.000	0.706**	0.065	0.920**
		P									1.000	0.582**	0.055	0.982**
10	Average length of fruit (cm)	G	-	-	-	-	-	-	-	-	-	1.000	0.394	0.706**
		P										1.000	0.347	0.581**
11	Average diameter of fruit (cm)	G	-	-	-	-	-	-	-	-	-	-	1.000	0.065
		P											1.000	0.054
12	Fruit yield t/ ha	G	-	-	-	-	-	-	-	-	-	-	-	1.000
		P												1.000

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

Conclusion

The maximum phenotypic and genotypic coefficient of variation was observed for characters *viz.* number of primary branches per vine, number of fruits per vine, fruit yield per vine, average weight of fruit and fruit yield per hectare in bitter gourd and remaining character shows moderate PCV and GCV in the cross Phule Green Gold x Hirkani and Hirkani x Phule Ujwala in F_4 generations. The characters showing wide range of variation provide ample scope for selecting the desirable plant types. High estimates of heritability for all characters indicating that they were least affected by environment and selection based on phenotypic performance would be reliable. The significant and positive correlation both at phenotypic and the genotypic level was observed between fruit yield per vine and the yield contributing characters. Thus association of characters should be considered for improvement.

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