

Original research article

Evaluation of genetic variability for yield improvement in Bitter gourd (*Momordica charantia*L.) genotypes

Abstract

The degree of genetic variability found in any particular germplasm is a major factor in determining the best breeding program or technique to be used. Exploitation of the natural genetic variability present within a crop species can aid in meeting the rising demand through the identification and modification of the adaptive and productive genes present. Breeders thus identify natural genetic variability as the key to crop improvement. The present investigation was undertaken at the Experimental field of Urban Technological Park Habbak, Srinagar, Jammu and Kashmir during *kharif*-2022. To investigate several aspects of genetic variability, including mean, range, PV, GV, PCV, GCV, heritability, genetic gain, and genetic advance among the genotypes, the experiment was set up in a Randomized Block Design with three replications and a plant spacing of 2×1 m for thirty genotypes. For every character under study, it was discovered that the estimates of the phenotypic coefficient of variation were marginally greater than the respective genotypic coefficient of variation, indicating a possible involvement of environment in the expression of these traits. Fruit yield hectare⁻¹ (q) exhibited the largest genotypic and phenotypic coefficient of variation (39.788 and 38.970). For yield hectare⁻¹ (q), high heritability and high genetic gain (0.95 and 78.62) were observed. This suggests that additive gene effects are most likely the cause of the heritability and increases the likelihood that this characteristic would be fixed by selection. For every characteristic, the estimates of broad sense heritability were high. All these factors help in selection of better parents for the development of commercial varieties/hybrids. Considering the potential nutritional and economic benefits of bitter gourd (*Momordica charantia*L.), there is an imperative necessity to isolate such breeding lines having desirable traits, high yield potential along with better quality.

Introduction

Bitter gourd, botanically known as "*Momordica charantia* L.", is a fairly well-known member of the herbaceous vine family "Cucurbitaceae". Bitter gourd is a quite popular "tropical and subtropical" commercially significant vegetable crop (Singh *et al.*, 2013). The name "*Momordica*" is derived from a Latin word, which means "to bite", which is in reference to the ridges present on the edges of the seed, appearing as if chewed. Some other common names used to refer to bitter gourd include bitter melon, balsam pear, maiden apple, casislla, karela, bitter cucumber and African cucumber (Morton, 1967 and Heiser, 1979). The origin of bitter gourd remains obscure, but most scientists presume this crop to be a native of Tropical Asia particularly Eastern India and South China. It is now being thoroughly cultivated across countries including India, Japan, China, Malaysia, Indonesia as well as tropical parts of Africa and Southern America.

Bitter gourd is well known for its high nutritive value, being especially rich in ascorbic acid and iron content (Behera, 2004 and Bharati *et al.*, 2010). The plant shows a high level of cross pollination and is in turn, highly heterozygous due to monoecism (Singh

etal., 2014). A useful medicinal and vegetable plant for maintaining human health, it is one of the most promising plants for diabetes management. Considerable variation in different nutrients, including carbohydrates, ascorbic acid, zinc, iron, calcium, magnesium, phosphorus and protein content has been observed in bitter gourd. (Zehra *et al.*, 2023). The fruits are frequently eaten boiled, fried, or stuffed and are utilized in a variety of ways as vegetable. In addition, the fruits are dehydrated, canned, and pickled. The plant is utilized medicinally in all parts. The fruits are useful in treating flatulence, blood disorders, rheumatism, and asthma. They also have cooling, digestive, laxative, antipyretic, and antidiabetic effects. The leaf is applied topically on wounds and taken internally as a laxative. The fruit powder is said to be beneficial to treat cancerous ulcers, leprosy, and wounds. It is said to be helpful for snakebite injuries. There is abortifacient activity in the roots. According to reports, the immunological deficiency virus (HIV-1) was inhibited in humans by the bitter gourd protein. Fresh leaf juice is recommended for diabetes in Ayurveda. (Sagar *et al.*, 2022).

In India, the bitter gourd crop covers 101,000 hectares and produces 1174 thousand metric tonnes of fresh yield annually (NHB, 2020-21). The leading bitter gourd producing states are Maharashtra, Uttar Pradesh, Gujarat, Rajasthan, Punjab, Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, West Bengal, Odisha, Assam and Bihar. In Kashmir, this crop is cultivated on a marginal scale and as a result, precise data on area and production is unavailable. (Aftab *et al.*, 2024).

For the release of a new variety, the first basic requirement is the presence of sufficient diversity amongst the genotypes to be crossed. Exploitation of the natural genetic variability present within a crop species can aid in meeting the rising demand through the identification and modification of the adaptive and productive genes present. Breeders thus identify natural genetic variability as the key to crop improvement. The degree of variability found in the available germplasm can be measured with the aid of the genotypic and phenotypic coefficients of variation. The more positively the yield and its component characters are correlated, the more effective the selection process is.

Materials and methods

Experimental style and layout

The current study was conducted during Kharif-2022 at the Urban Technological Park Experimental Field of SKUAST, Habbak Srinagar, Jammu & Kashmir. Situated between 34.16° North latitude and 74.83° East longitude, at a height of 1608 meters above mean sea level, is the Urban Technological Park, Habbak. The mild summers are a hallmark of the temperate climate. In October and August-September, the mean minimum and maximum recorded temperatures are 2.42 °C and 30°C, respectively. June is the month when there is the most rainfall received.

During Kharif-2022, thirty genotypes of bitter gourd with distinct phenotypes that were gathered from different sources were assessed for a variety of yield-related characteristics. Three replications of the single factor experiment were set up using a Randomized Complete Block Design (RCBD). For every replication, five plants per genotype were planted at a spacing of 2 × 1 m between rows and plants, respectively. To generate a healthy crop, recommended cultural techniques were adhered to during the growth and developmental phase.

Observations were recorded on twenty four traits viz. days to appearance of 1st male flower, days to appearance of 1st female flower, number of male flowers plant⁻¹, node at which 1st female flower appears, number of female flowers plant⁻¹, vine length (m), fruit length (cm), fruit diameter (cm), number of fruits plant⁻¹, average fruit weight (g), leaf area (cm²), 100 seed weight (g), number of seeds fruit⁻¹, seed weight fruit⁻¹ (g), days to 1st fruit harvest, fruit yield plant⁻¹ (kg), fruit yield hectare⁻¹ (q), TSS (°Brix), crude protein (%), vitamin C content (mg/100g), iron content (mg/100g), total chlorophyll content (mg/100g), dry matter content (%) and total phenols (mg/100g). The observations on different quantitative and quality parameters were recorded from three randomly selected plants from each line of all replications.

Statistical analysis

Analysis of variance

According to the procedure outlined by Panse and Sukhatme (1957), analysis of variance was performed for each character in accordance with the design of the experiment (RCBD). The significance levels for the treatment means were 5% and 1%.

Estimation of the components of variances

Genotypic variance

Genotypic variance was calculated by using the method suggested by Johnson *et al.* (1955).

$$\sigma_g^2 = \frac{MSt - MSe}{r}$$

Where,

$\hat{\sigma}_g^2$ = Genotypic variance,

MSG = mean sum of squares due to genotypes,

MSE = mean sum of squares due to error and

r = number of replications

Phenotypic variance

Phenotypic variance was estimated as per the procedure described by Johnson *et al.* (1955).

$$\hat{\sigma}_p^2 = \hat{\sigma}_g^2 + \hat{\sigma}_e^2$$

Where,

$\hat{\sigma}_p^2$ Phenotypic variance

$\hat{\sigma}_g^2$ genotypic variance and

$\hat{\sigma}^2$ error variance

Phenotypic and genotypic co-efficient of variation

Burton (1952) provided the following formulas, which were used to calculate the genotypic and phenotypic co-efficients of variation (GCV) for the multitude of parameters under study:

$$PCV = \frac{\sqrt{\hat{\sigma}^2 p}}{\bar{x}} \times 100$$

Where,

$\hat{\sigma}^2 p$ Phenotypic variance and

\bar{x} Grand mean of the character under study

$$GCV = \frac{\sqrt{\hat{\sigma}^2 g}}{\bar{x}} \times 100$$

Where,

Genotypic variance and

Grand mean of the character under study

The estimates of PCV and GCV were classified into low, moderate and high according to Sivasubramanian and Madhavmenon (1973) as follows:

0 – 10%: Low

10 – 20%: Moderate

> 20%: High

Heritability (broad sense)

The ratio of genotypic variance to phenotypic variance was used to determine the heritability (h^2) for yield and its component traits, which was then reported as percentage. The computation was carried out following the guidelines provided by Hanson et al. (1956), Johnson et al. (1955), and Burton and Devane (1953).

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p}$$

Where,

- h^2 = Estimate of heritability in broad sense,
 σ^2g = Genotypic variance, and
 σ^2p = Phenotypic variance

The estimates of broad sense heritability, expressed in percentage were then categorized as low, moderate and high as suggested by Robinson *et al.* (1949):

0-30%: Low

30-60%: Moderate

> 60%: High

Genetic advance

Genetic advance at 5 per cent selection intensity was worked out by using the procedure suggested by Lush (1949) and Johnson *et al.* (1955).

$$GA = \frac{\sigma^2g}{\sigma^2p} \times (\sigma^2p)^{1/2} \times K$$

Where,

- GA = Genetic advance of the trait,
 σ^2g = genotypic variance of the trait,
 σ^2p = phenotypic variance of the trait, and
K = selection differential; (K = 2.06 at 5% selection intensity)

Expected genetic gain (genetic advance as per cent of mean)

It was estimated as per the method suggested by Johnson *et al.* (1955).

$$\text{Genetic gain} = \frac{GA}{\bar{X}} \times 100$$

Where,

- G.A. = Genetic advance of the trait
 \bar{X} = mean of the trait

The GA as per cent of mean was categorised as low, moderate and high as suggested by Johnson *et al.* (1955).

0-10%: Low

10-20%: Moderate

>20%: High

All the above computations were carried out using the software Windostat at the Division of Genetics and Plant Breeding, SKUAST-Kashmir, Shalimar and “Variability package” in R software at the Division of Agri-Statistics, SKUAST-K, Shalimar.

Results and discussion

The analysis of variance disclosed that all the twenty-four characters exhibited highly significant differences among all the genotypes studied, thus suggesting existence of sufficient variability in the germplasm studied (Table-1a and 1b).

Range values for the various characters under study (Table-2) showed that there was enough variation for each character, which is necessary before selecting for improvement. The results obtained are in conformity with the findings of Islam *et al.* (2009), Yadav *et al.* (2013), Chinthan *et al.* (2021), Sowmya *et al.* (2021) and Nithinkumaret *et al.* (2022).

Since it encompasses elements of genotype, environment, and genotype × environment interaction and does not identify which character is exhibiting a higher degree of variability, the range in the values represents the amount of phenotypic variability, which makes it unstable. Additionally, dominance (a non-heritable factor), epistasis (non-allelic interaction), and additive gene effect (a heritable factor) all affect a crop's phenotypic behaviour. Therefore, the observed variability must be divided into the phenotypic and genotypic coefficients of variation. This will finally illustrate how variable different traits are.

Table-2 displays the estimated genotypic and phenotypic coefficients of variation for each character under study. The environment plays a significant impact in the expression of the traits that are being observed, as seen by the generally nearly identical genotypic and phenotypic coefficients of variation, with somewhat larger phenotypic coefficients of variation. This was consistent with research conducted by Maurya *et al.* (2018), Ziaul *et al.* (2019), Prakash *et al.* (2021), Reddy *et al.* (2021), Tiwari *et al.* (2021), Rani *et al.* (2015), and Ziaul *et al.* (2021).

Traits with moderate to high coefficients of variation have a greater chance of improving through selection. Wide range of variability and high estimates of the genotypic and phenotypic coefficients of variation further imply that these traits would be responsive to selection.

It is evident from the data presented in Table-2 that the number of male flowers plant⁻¹ (27.77, 27.38), node number at which 1st female flower appeared (22.33, 21.86), number of female flowers plant⁻¹ (30.51, 30.33), vine length (32.59, 32.15), number of fruits plant⁻¹ (34.73, 34.59), leaf area (26.61, 26.30), fruit yield plant⁻¹ (39.34, 38.41), fruit yield hectare⁻¹ (39.78, 38.97), iron content (27.58, 27.38), total chlorophyll content (35.07, 34.94) and total phenols (20.93, 20.53) exhibited high values of genotypic and phenotypic coefficients of variation, respectively, suggesting that these genotypes had a wide genetic base for these characters. Fruit length (17.20, 16.90), fruit diameter (11.78, 11.03), average fruit weight (15.69, 15.41), 100 seed weight (19.35, 19.26), number of seeds fruit⁻¹ (20.00, 19.78), seed weight fruit⁻¹ (19.09, 18.77), TSS (10.17, 10.11), crude protein content (14.52, 14.41), vitamin C content (14.25, 14.10) and dry matter content (17.85, 17.77) demonstrated

moderate phenotypic and genotypic coefficients of variation suggesting the existence of moderate variability in the genetic stock studied. Low PCV and GCV values were observed for the traits; days to appearance of 1st male flower (7.51, 7.45), days to appearance of 1st female flower (6.67, 6.58) and days to 1st fruit harvest (6.56, 6.52). The results were in tune with the findings of Yadav *et al.* (2013), Pathak *et al.* (2014), Maurya *et al.* (2018), Talukder *et al.* (2018), Ziaul *et al.* (2019) and Sowmya *et al.* (2021).

The genotypic and phenotypic coefficients of variation do not accurately represent the degree of a character's heredity nor do they aid in determining the percentage of variation that is genuinely heritable. The heritability of a trait is therefore a reliable approach in such a situation because it allows the breeder to determine how much selection pressure to apply in a given context, thereby separating the effect of the environment from overall variability. It makes assessing the contributions of environmental and genetic factors to the observable phenotypic variance easier. According to Panse and Sukhatme (1957) and Johnson *et al.* (1955), the estimation of heritability has a greater role to play in determining the efficiency of character selection if it is taken into account in conjunction with the projected genetic advance. Moreover, the amount of genetic gain is closely correlated with the progress of selection. Hence, traits with high heritability and high genetic gain experience the effects of selection more quickly. High GAM (Genetic Advance as % of Mean) in conjunction with high heritability suggests that selection could be successful since the traits are likely being governed by additive gene action. When high heritability is demonstrated as a result of a favourable environment rather than genotype, selection for such traits may not be profitable. High heritability with low GAM suggests the importance of non-additive gene action. Additive gene effects are generally predominant in the case of low heritability with high GAM. In certain situations, significant environmental effects lead to low heritability, and selection may be successful. Low GAM and low heritability suggest that selection would be futile because character is heavily impacted by environmental factors.

All of the characters in the current study had high heritability (b.s.), which ranged from 87 to 99 percent. This suggests that genetic constitution plays a major role in character expression and that selection based on phenotypic expression can be trusted because the characters are less affected by environmental factors and are effectively passed down to the progeny. Pathak *et al.* (2014), Singh *et al.* (2015), Alekar *et al.* (2019), Prasanth *et al.* (2020), and Sowmya *et al.* (2021) all reported similar outcomes.

The characters *viz.*, number of male flowers plant⁻¹, node number at which 1st female flower appeared, number of female flowers plant⁻¹, vine length,, fruit length, average fruit weight, number of fruits plant⁻¹, leaf area, 100 seed weight, number of seeds fruit⁻¹, seed weight fruit⁻¹, fruit yield plant⁻¹, fruit yield hectare⁻¹, iron content, total chlorophyll content, dry matter content and total phenols shown substantial genetic advance as a percentage of mean (GAM) and high estimates of heritability, suggesting that additive gene action predominates in the control of these traits. This implies that actual advancements in yield-based selection could be accomplished. These results are in conformity with several workers *viz.* Islam *et al.* (2009), Alekar *et al.* (2019), Ziaul *et al.* (2019), Prasanth *et al.* (2020) and Sowmya *et al.* (2021).

A key factor that determines the hybrid or variety's commercial viability is fruit yield hectare⁻¹. Therefore, in every breeding effort, this feature should be given top importance. The prospect of choosing high yielding cultivars from the current collection was suggested by

the trait's high heritability and high genetic progress as a percentage of mean. Islam *et al.* (2009), Kumari *et al.* (2018), Nithinkumaret *al.* (2022), and Wan *et al.* (2022) all backed up this claim.

Table-1a: Analysis of variance (ANOVA) with respect to MSS for various growth, yield attributing and quality characters in bitter gourd (*Momordica charantia*L.)

S. No.	Source of variation	d.f	Mean sum of squares												
			Days to 1 st male flower appearance	Days to 1 st female flower	No. of male flowers plant ⁻¹	Node number at which 1 st female flower appeared	No. of female flowers plant ⁻¹	Vine length (m)	Fruit length (cm)	Fruit diameter (cm)	No. of fruits plant ⁻¹	Average fruit weight (g)	Leaf area (cm ²)	100 seed weight (g)	
1.	Replication	2	0.99	0.84	3.71	1.10	1.58	0.15*	0.59	0.18*	1.25	3.10	2.80	1.03	
2.	Genotype	29	51.53**	52.99**	20464.60**	24.69**	155.12**	2.15**	20.72**	0.28**	135.50**	508.77**	905.61**	83.72**	
3.	Error	58	0.26	0.45	1.90	0.35	0.59	0.01	0.24	0.01	0.48	0.91	0.76	0.26	

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

Table-1b: Analysis of variance (ANOVA) with respect to MSS for various growth, yield attributing and quality characters in bitter gourd (*Momordica charantia*L.)

S. No.	Source of variation	d.f	Mean sum of squares												
			No. of seeds fruit ⁻¹	Seed weight fruit ⁻¹	Days to 1 st fruit harvest	Fruit yield plant ⁻¹ (kg)	Fruit yield hectare ⁻¹ (q)	TSS (°Brix)	Crude protein content (%)	Vitamin C content (mg 100g ⁻¹)	Iron content (mg 100g ⁻¹)	Total chlorophyll content (mg 100g ⁻¹)	Dry matter content (%)	Total phenols (mg 100g ⁻¹)	
1.	Replication	2	1.31	0.08	0.59	0.26*	15.63	0.92	0.25	0.39	0.86	1.50	1.14	0.34	
2.	Genotype	29	44.44**	5.82**	76.52**	1.18**	2871**	0.57**	13.82**	159.61**	0.04**	20463.50**	11.05**	182.73**	
3.	Error	58	0.33	0.06	0.36	0.01	4.09	0.19	0.15	0.10	0.40	0.53	0.70	0.10	

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

Table-2: Estimates of mean, range, phenotypic variance, genotypic variance, phenotypic and genotypic coefficients of variation, heritability and genetic advance (as % of mean) for various growth, yield attributing and quality characters in bitter gourd (*Momordica charantia* L.)

S. No.	Parameters	Mean	Range	Phenotypic variance (PV)	Genotypic variance (GV)	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Heritability h ² (broad sense)	Genetic gain (Genetic advance as % of mean)
1.	Days to appearance of 1 st male flower	55.45	46.22-62.25	17.35	17.09	7.51	7.45	0.98	15.24
2.	Days to appearance of 1 st female flower	63.53	57.22-72.18	17.96	17.51	6.67	6.58	0.97	13.39
3.	Number of male flowers plant ⁻¹	297.35	170.02-432.81	6822.77	6630.81	27.77	27.38	0.97	55.61
4.	Node number at which 1 st female flower appeared	13.03	6.72-19.38	8.46	8.11	22.33	21.86	0.95	44.08
5.	Number of female flowers plant ⁻¹	23.65	12.71-35.23	52.10	51.50	30.51	30.33	0.98	62.13
6.	Vine length (m)	2.62	1.48-4.53	0.73	0.71	32.59	32.15	0.97	65.35
7.	Fruit length (cm)	15.46	10.81-23.21	7.07	6.82	17.20	16.90	0.96	34.20
8.	Fruit diameter (cm)	2.72	2.06-3.43	0.10	0.09	11.78	11.032	0.87	21.26
9.	Number of fruits plant ⁻¹	19.41	9.01-30.40	45.48	45.00	34.73	34.54	0.98	70.79
10.	Average fruit weight (g)	83.13	60.58-120.88	170.19	164.32	15.69	15.41	0.96	31.20
11.	Leaf area (cm ²)	65.87	33.49-109.90	307.37	300.21	26.61	26.30	0.97	53.54
12.	100 seed weight (g)	27.37	16.52-36.80	28.08	27.81	19.35	19.26	0.99	39.50
13.	Number of seeds fruit ⁻¹	19.38	12.31-28.19	15.04	14.70	20.00	19.78	0.97	40.29
14.	Seed weight fruit ⁻¹ (g)	7.38	4.73-10.50	1.98	1.92	19.09	18.77	0.96	38.04
15.	Days to 1 st fruit harvest	77.28	70.04-86.06	25.74	25.38	6.56	6.52	0.98	13.33
16.	Fruit yield plant ⁻¹ (kg)	1.62	0.70-2.94	0.40	0.388	39.34	38.41	0.95	77.28
17.	Fruit yield hectare ⁻¹ (q)	77.85	32.53-143.60	959.72	920.63	39.78	38.97	0.95	78.62
18.	TSS (°Brix)	4.31	3.61-5.16	0.19	0.19	10.17	10.11	0.98	20.71
19.	Crude protein content (%)	14.78	11.00-19.63	4.61	4.54	14.52	14.41	0.98	29.48
20.	Vitamin C content (mg 100g ⁻¹)	51.16	41.26-66.90	53.20	52.10	14.25	14.10	0.97	28.75
21.	Iron content (mg 100g ⁻¹)	0.43	0.25-0.67	0.01	0.01	27.58	27.38	0.98	56.22
22.	Total chlorophyll content (mg 100g ⁻¹)	235.46	102.33-354.72	6821.16	6772.34	35.07	34.94	0.99	71.73
23.	Dry matter content (%)	10.80	8.07-14.02	3.72	3.68	17.85	17.77	0.99	36.43
24.	Total phenols (mg 100g ⁻¹)	37.28	24.26-50.07	60.91	58.96	20.93	20.59	0.96	41.73

Conclusion

Analysis of variance revealed significant variation existed among various characters under study; this indicates that there is tremendous potential for converging the elite allelic resources present in these bitter gourd genotypes through a systematic breeding and selection approach, with the goal of recovering high yielding recombinants, with good quality characteristics.

For every character under investigation, the estimates of phenotypic variances were greater than the corresponding genotypic variances, demonstrating the influence of environment on the expression of these traits, according to the results obtained for various variability and heritability parameters. In order to draw meaningful findings, the phenotypic and genotypic coefficients of variation were also computed, since these values by themselves do not offer a way to evaluate the nature of genetic variability. In general, the phenotypic and genotypic coefficients of variation were almost similar with somewhat higher values phenotypic coefficients of variation indicating minor role of environment in the expression of the studied traits. The phenotypic and genotypic coefficients of variability ranged from 6.65-39.78 and 6.52-38.97 respectively. The highest phenotypic and genotypic coefficients of variability in the present investigation were observed for the trait fruit yield hectare⁻¹ (39.78, 38.97) followed by fruit yield plant⁻¹ (39.34, 38.40), total chlorophyll content (35.07, 34.94) and number of fruits plant⁻¹ (34.73, 34.59). The present investigation indicates a great scope of fast improvement of majority of the traits studied as these characters in general exhibited high heritability coupled with high genetic advance (as per cent of mean), except for the traits days to appearance of 1st male flower, days to appearance of 1st female flower and days to 1st fruit harvest which although had high heritability but it was coupled with low genetic advance (as per cent of mean).

Heritability (b. s.) was found to be high for all the characters and ranged from 87 to 99 per cent indicating that the characters are less influenced by environmental effects and are likely to be effectively transmitted to the progeny. The present investigation indicates a great scope of fast improvement of majority of the traits studied as these characters in general exhibited high heritability coupled with high genetic advance (as per cent of mean) indicating the preponderance of additive gene action for control of these traits. This suggests that real progress in improvement through selection could be made for yield and thus the chances of fixing by selection are more to improve such traits through pure line selection, mass selection, progeny selection, hybridization and selection through pedigree breeding. However, an exception in this regard was observed for the traits; days to appearance of 1st male flower, days to appearance of 1st female flower and days to 1st fruit harvest which although had high heritability but it was coupled with low genetic advance (as per cent of mean). These characters are likely being governed by non-additive gene action and thus, recombinant breeding would prove beneficial for improving them.

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