Mysore J. Agric. Sci., 60 (2) : 222-237 (2026)

Morphological Studies in Bitter Gourd (*Momordica charantia* L.) Germplasm

Naganagouda B. Patil[1], S. N. Vasudevan[2], Sanjay Dwivedi[3], Parashivamurthy[4], R. Siddaraju[5], S. Ramesh[6], Kavita Kandpal[7] and N. Nagesh[8]

[1,2,4&5]Department of Seed Science and Technology, [6]Department of Genetics and Plant Breeding, [7]Department of Horticulture, [8]Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065, [3]ORBI Seeds International Pvt. Ltd. Bengaluru

e-Mail : np942418@gmail.com

Authors Contribution

Naganagouda B. Patil : Conceptualization, design, manuscript writing, curation, data analysis and tabulation of results

S. N. Vasudevan & Sanjay Dwivedi : Conceptualization, design, manuscript editing, guidance and supervision

Parashivamurthy ; R. Siddaraju ; S. Ramesh ; Kavita Kandpal & N. Nagesh : Supervision and helped to shape the research

Corresponding Author :

Naganagouda B. Patil

Received : December 2025

Accepted : January 2026

Abstract

The present study aimed to characterize thirty bitter gourd (*Momordica charantia* L.) germplasm for growth, yield and seed attributes using PPV & FRA descriptors. Significant variability was recorded across all traits. Days to anthesis of the first staminate and pistillate flowers ranged from 32.43-45.46 days and 38.28-51.01 days, respectively. The number of staminate flowers per plant varied from 287-404, while pistillate flowers varried from 15.10-21.91. Yield attributes also displayed marked diversity. The number of fruits per plant ranged from 10.26-12.84, fruit length from 12.76-29.75 cm, fruit diameter from 2.96-4.94 cm and fruit weight from 60.64-161.78 g. The number of seeds per fruit varried between 12.13-33.67. Fruit yield per plant varied from 0.76-1.90 kg, while seed yield ranged from 29.70-121.13 g/plant and 4.26-17.39 q/ha. Seed traits also showed significant variation, with seed size ranging from 70.88-112.14 mm², seed density from 0.15-0.73 g/cc, seed coat thickness from 0.36-0.75 mm and husk-to-kernel ratio between 0.34-0.95 per cent. The wide variability observed across growth, yield and seed traits reflects the combined influence of genetic factors and genotype × environment interactions. These findings underline the importance of this germplasm as a valuable genetic resource for breeding programs aimed at yield improvement, seed quality enhancement and varietal development in bitter gourd.

Keywords : Bitter gourd, Germplasm, Variability, Growth traits, Yield, Seed attributes

Bitter gourd (*Momordica charantia* L.) represents one of the most significant commercial crops in terms of both economic and medicinal significance. It possesses numerous culinary applications, particularly throughout South, South-East and East Asia. Additionally, it is cultivated as an ornamental flora and is widely utilized in traditional medicinal practices (Heiser, 1979). This crop is referred to by various designations including bitter gourd, balsam pear, bitter melon, bitter cucumber and African cucumber (Heiser, 1979). This genus encompasses approximately 23 species (Jeffrey, 1967) within the African continent alone. Among the cultivated species, one finds *Momordica charantia*, commonly known as bitter gourd or karela in India, *M. cochinchinensis*, recognized as sweet gourd or golkakora in Assam and the North-Eastern regions, *M. dioica*, termed kakrol in Bengal, Bihar and Orissa, as well as *M. balsamina* (balsam apple) and *M. cymbalaria* (syn. *M. tuberosa*). This genus is predominantly indigenous to the tropical zones of Asia, Polynesia,

as well as Tropical Africa and South America. The bitter gourd is specifically believed to have originated in Tropical Asia, particularly within the regions of East India and South China (Laxuman, 2005).

Bitter gourd is recognized for its nutritional benefits and has been the subject of various studies focusing on its genetic diversity and morphological traits. The genetic diversity present within the existing germplasm is a critical factor influencing the success of breeding initiatives. A pivotal aspect of assessing genetic diversity is often regarded as the examination of the biological characteristics of the crop. It is essential to ascertain whether the observed variability is attributable to heritable factors or environmental influences, given that most economically significant plant traits are polygenic and significantly shaped by environmental conditions. Traits exhibiting high genetic diversity heritability and potential for genetic gain are of greater significance for selection processes. To harness the economic potential of the crop, it is crucial to identify breeding lines that exhibit optimal horticultural attributes, superior quality and high yield potential. This study aims to provide insights into the morphological traits of bitter gourd, facilitating the development of effective breeding strategies to enhance its agronomic performance and nutritional value.

Morphological characterization in bitter gourd is essential for genetic resource management, diversity studies, varietal development, registration and meeting farmer/market demands. Though it may be influenced by environment, it remains the most practical and cost-effective method of initial characterization before molecular markers are applied. This approach not only aids in the identification of desirable traits but also enhances the efficiency of breeding programmes aimed at improving the overall quality and resilience of bitter gourd varieties.

Material and Methods

The current investigation entitled 'Morphological studies in bitter gourd (*Momordica charantia* L.) germplasm' was conducted at the Research and Development Station of ORBI Seeds International Private Limited in Sadahalli, spanning the *rabi*/ summer seasons of 2022 in a randomized complete block design with three replications, allowing for accurate assessment of the morphological traits across different accessions. Simultaneously, laboratory experiments were executed at the Department of Seed Science and Technology at Gandhi Krishi Vignan Kendra, University of Agricultural Sciences, Bangalore.

Plant Material

Thirty bitter gourd germplasm accessions were sourced from ORBI Seeds International Pvt. Ltd. Bangalore, ensuring a comprehensive representation of the genetic variability within the species.

Data Collection

Growth Attributes

Days to Anthesis of First Staminate Flowers

Number of days taken from date of sowing tothe anthesis of first male flower in the five randomly selected and tagged vines was recorded.

Days to Anthesis of First Pistillate Flowers

Number of days taken from date of sowing tothe anthesis of first female flower in the five randomly selected and tagged vines was recorded.

Number of Staminate Flowers Per Plant

Number of male flowers per plant was counted from tagged plants up to harvest. The average of five plants was computed and expressed as number of staminate flowers per plant.

Number of Pistillate Flowers Per Plant

Number of female flowers per plant was counted from tagged plant up to harvest. The average of five plants was computed and expressed as number of pistillate flowers per plant.

Vine Length at Final Harvest (cm)

The length of the five randomly selected vines were measured from the ground level of the main vine to

the tip of the vine with the help of meter scale at maturity. The average was worked out and expressed in centimeter.

Sex Ratio

The number of male and female flowers were counted on regular basis from five randomly tagged vines until the crop showed the signs of termination of flowering and ratio of male to female flowers was calculated by using the below formula,

$$\text{Sex ratio} = \frac{\text{Total number of male flowers per plant}}{\text{Total number of female flowers per plant}}$$

Yield Attributes

Number of Fruits Per Plant

The number of matured fruits harvested from the labelled vines were counted; the average was worked out and expressed as number of fruits per plant.

Fruit Length (cm)

Length of the five fruits obtained from five randomly selected vines was measured from the base of the pedicel to the tip of the fruit at ripened stage and the average fruit length was computed and the mean was expressed in centimeter.

Fruit Diameter (cm)

Diameter of fruits was recorded on same five fruits from plants of a plot in each replication on which fruit length was measured. The measurement of fruit diameter at the middle portion of the fruit was taken with the help of vernier calipers and the average fruit diameter was calculated.

Average Fruit Weight (g)

At maturity, the weight of five fruits harvested from the tagged vine was taken and the mean values were recorded as average fruit weight in grams.

Number of Seeds Per Fruit

The fruits were cut and the total number of seeds per fruit was counted and recorded with the help of five randomly selected plants in each replication.

Seed Yield Per Plant (g)

The seed yield per plant was calculated by weighing all seeds / plant and expressed in grams.

Seed Yield Per Hectare (q)

Seed yield per hectare was determined based plant population in an hectare by multiplying with one plant yield and expressed in quintal.

Fruit Yield Per Plant (kg)

Fruit yield per plant was calculated by multiplying the number fruits per plant with the average fruit weight and expressed in kilograms.

Fruit Yield Per Hectare (t/ha)

The fruit yield per hectare was worked out based on the fruit weight per net plot basis using below formula and expressed in tons per hectare.

$$\text{Fruit yield per hectare (t/ha)} = \frac{\text{Fruit yield per plot (kg)}}{\text{plot area}} \times \frac{10{,}000}{1000}$$

Seed Attributes

Seed Size (mm^2)

Seed samples of the bitter gourd germplasm were evaluated for morphometric characters, 10 seeds drawn randomly from each treatment in three replications were analyzed under BIOVIS PSM seed image analyzer for seed size and expressed in mm^2.

Seed Density (g/cc)

Seed density was done by displacement method by using toluene. Known quantity of seeds were filled with known quantity of toluene in a measuring cylinder. The rise in volume was recorded and the seed density was recorded by using the formula given below and expressed in g/cc.

Seed Coat Thickness (mm)

Seed coat thickness measurement was done by vernier calipers and expressed in mm.

Husk to Kernel Ratio (%)

Husk to kernel ratio was taken by removing the seed coat of 10 grams of seed. Seed coat and kernel were separately weighed and calculated as percentage.

Seed Texture

Seed structure was recorded manually by feeling the texture between the fingers and classified into rough and smooth according to PPV&FRA guidelines.

Seed Colour

Colour of the seeds were recorded by visual observation of individual germplasm and classified into brown, dark brown, light brown, yellow and black according to PPV&FRA guidelines.

Seed: Indentation of Margin

Indentation of margin of the seeds was recorded by visual observation of individual germplasm and classified into small, medium and large according to PPV&FRA guidelines.

Statistical Analysis

The data of different experiments were statistically analysed for valid inference and interpretation and definite conclusion. The analyses were done following procedures outlined by Sundararaj *et al*. (1972) adopting 'Fisher's Analysis of Variance Techniques'. Wherever necessary the per cent values were transformed to angular and square-root transformation values before analysis. The critical differences (CD) were calculated at 5 per cent probability level. The data were tested for statistical significance. If the 'F' test wasnon-significant, it was indicated by the letters NS.

Results and Discussion

Findings of the present study are shown in Table 1-6 and Fig. 1-2.

Growth Attributes

Significant variations were observed among the 30 germplasm in relation to the duration until anthesis of the first staminate and pistillate flower, number of staminate and pistillate flowers produced per plant (Table 1 and Fig. 1).

Table 1

Performance of bitter gourd genotypes for growth parameters *viz.*, days to anthesis of 1st staminate and pistillate flower, number of staminate and pistillate flowers per plant

Germplasm	Days to anthesis of 1st staminate flower	Days to anthesis of 1st pistillate flower	Number of staminate flowers per plant	Number of pistillate flowers per plant
ABTG-01	42.96	48.42	289	15.97
ABTG-02	39.84	46.70	287	15.40
ABTG-03	35.86	41.82	318	16.27
ABTG-05	40.69	45.47	301	15.10
ABTG-06	38.09	44.92	328	15.76
ABTG-07	36.29	43.20	340	16.84
ABTG-08	37.88	44.88	308	17.49
ABTG-09	35.92	41.91	310	16.97
ABTG-10	35.82	41.90	320	20.16
83-001	42.13	48.22	353	15.46
83-002	38.62	44.67	359	15.97
83-003	40.21	46.12	361	16.17
83-004	41.26	47.35	350	18.14
83-005	41.06	47.86	375	18.09
83-006	41.67	49.25	347	17.11
83-008	39.77	46.64	384	17.37

Continued....

TABLE 1 Continued....

Germplasm	Days to anthesis of 1st staminate flower	Days to anthesis of 1st pistillate flower	Number of staminate flowers per plant	Number of pistillate flowers per plant
83-009	35.78	42.02	367	15.40
83-010	35.42	43.33	391	17.26
83-012	35.48	43.82	301	18.88
83-013	35.57	40.97	311	18.94
83-014	37.64	42.85	404	17.34
83-015	42.96	49.00	395	16.79
83-016	42.90	47.77	392	17.27
83-017	45.46	50.53	359	15.77
83-019	32.43	38.28	344	16.26
83-021	32.88	39.66	356	19.16
83-023	44.80	51.01	370	20.27
83-024	35.23	42.11	353	21.91
83-026	44.88	50.93	340	20.31
83-029	35.45	42.14	388	18.13
Mean	38.83	45.13	346.67	17.40
S.Em±	1.82	2.20	12.25	1.06
CD at 5 %	5.15	6.22	34.68	3.01
CV (%)	8.12	8.43	6.12	10.58

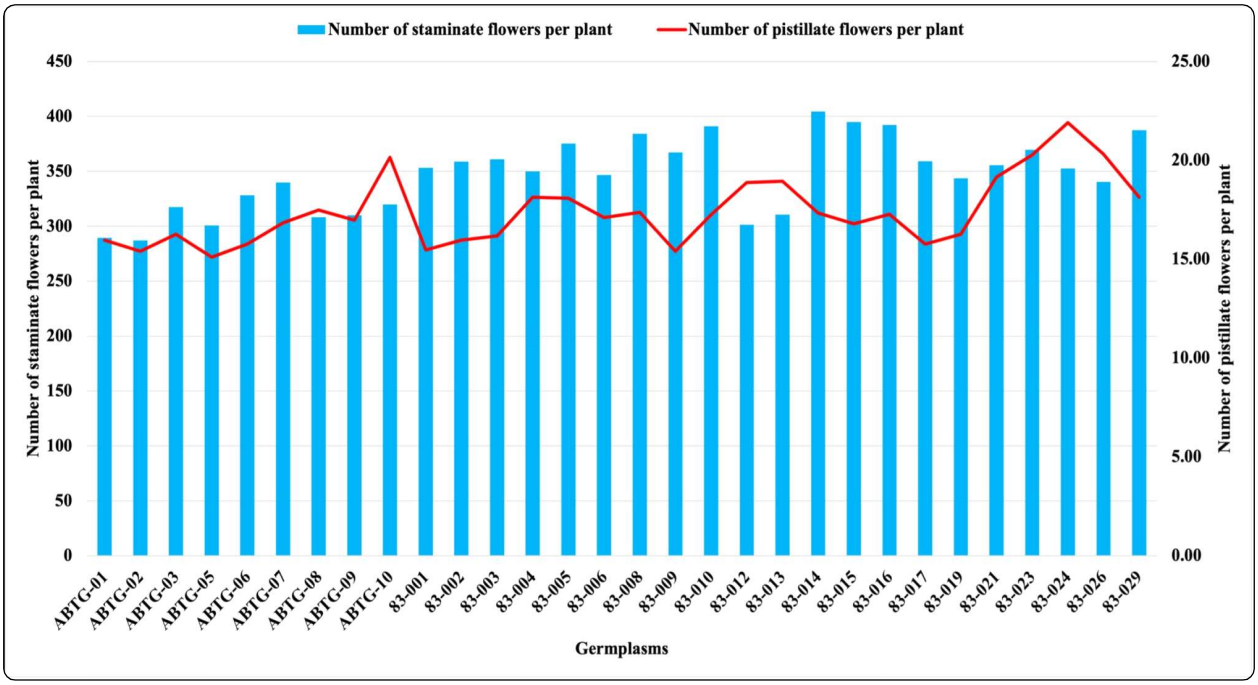

Fig. 1 : Number of staminate and pistillate flowers per plant in bitter gourd germplasm

The duration to anthesis of the initial staminate flower across the bitter gourd germplasm displayed a spectrum ranging from 32.43 days to 45.46 days, with an average value of 38.83 days. The germplasm 83-019 demonstrated the earliest onset of anthesis for the first staminate flower, occurring at an average of 32.43 days, followed closely by the genotype 83-021 (32.88 days), 83-024 (35.23 days), 83-010 (35.42 days) and 83-029 (35.45 days). Conversely, accession 83-017 exhibited a markedly prolonged duration to anthesis of the first staminate flower, recorded at 45.46 days, with subsequent germplasms such as 83-026 (44.88 days), 83-023 (44.80 days), ABTG-01 (42.96 days) and 83-015 (42.96 days) trailing closely behind.

The duration to anthesis of the initial pistillate flower across the bitter gourd germplasm displayed a spectrum ranging from 38.28 days to 51.01 days, with an average value of 45.13 days. The germplasm 83-019 demonstrated the earliest onset of anthesis for the first pistillate flower, occurring at an average of 38.28 days, followed closely by 83-021 (39.66 days), 83-013 (40.97 days), ABTG-03 (41.82 days) and ABTG-10 (41.90 days). Conversely, germplasm 83-023 exhibited a markedly prolonged duration to anthesis of the first pistillate flower, recorded at 51.01 days, followed by 83-026 (50.93 days), 83-017 (50.53 days), 83-006 (49.25 days) and 83-015 (49.00 days) trailing closely behind.

The production of staminate flowers per individual plant in the bitter gourd germplasm revealed a spectrum extending from 287 to 404, with a calculated mean of 346.67. The genotype 83-014 exhibited a significantly increased frequency of male flowers per plant (404), followed by 83-015 (395), 83-016 (392), 83-010 (391) and 83-008 (384). In contrast, the germplasm ABTG-02 demonstrated the lowest frequency of staminate flowers per individual plant, presenting a calculated mean of 287, while germplasms ABTG-01 (289), ABTG-05 (301), 83-012 (301) and ABTG-08 (308) were documented immediately preceding this observation.

The production of pistillate flowers per individual plant in the bitter gourd germplasm varied from 15.10 to 21.91, with a calculated mean of 17.40. The germplasm 83-024 exhibited a significantly increased incidence of female flowers per plant (21.91), followed by *viz.*, 83-026 (20.31), 83-023 (20.27), ABTG-10 (20.16) and 83-021 (19.16) closely followed. Conversely, the germplasm ABTG-05 exhibited the lowest incidence of pistillate flowers per individual plant, yielding an average of 15.10, whereas the germplasms ABTG-02 (15.40), 83-009 (15.40) and 83-001 (15.46) were sequentially positioned preceding it.

Significant variations were observed among the thirty germplasm with respect to the vine length upon achieving maturity, sex ratio, number of fruits per plant and fruit length (Table 2).

Table 2

Performance of bitter gourd genotypes for growth and yield parameters *viz.,* vine length at final harvest, sex ratio, number of fruits per plant and fruit length

Germplasm	Vine length at final harvest (cm)	Sex ratio (M:F)	Number of fruits per plant	Fruit length (cm)
ABTG-01	316	18.20	10.60	26.51
ABTG-02	340	18.95	10.93	28.16
ABTG-03	317	19.53	11.73	29.75
ABTG-05	318	20.22	11.06	26.50
ABTG-06	328	21.09	10.59	22.12
ABTG-07	248	20.50	11.67	21.85
ABTG-08	276	17.69	11.80	19.38

Continued....

TABLE 2 Continued....

Germplasm	Vine length at final harvest (cm)	Sex ratio (M:F)	Number of fruits per plant	Fruit length (cm)
ABTG-09	290	18.54	10.26	21.59
ABTG-10	220	16.05	11.99	25.75
83-001	325	23.10	12.03	25.28
83-002	223	22.83	11.46	17.52
83-003	250	22.82	11.77	19.13
83-004	245	20.46	10.99	13.38
83-005	219	21.74	12.40	13.26
83-006	340	20.91	11.19	28.35
83-008	326	22.23	11.91	24.72
83-009	283	24.44	12.18	20.89
83-010	245	22.80	11.98	15.95
83-012	237	16.21	12.84	22.57
83-013	371	16.61	12.46	26.94
83-014	323	23.71	11.14	21.75
83-015	223	23.70	11.53	18.80
83-016	237	22.83	12.47	17.26
83-017	217	22.91	12.73	12.76
83-019	303	21.33	11.26	24.40
83-021	213	18.77	11.73	20.72
83-023	341	18.39	12.06	27.17
83-024	317	16.74	11.60	24.31
83-026	346	17.28	10.53	28.00
83-029	265	22.21	11.35	25.15
Mean	283.29	20.43	11.61	22.33
S.Em±	20.58	1.48	0.48	1.19
CD at 5 %	58.25	4.19	1.36	3.37
CV (%)	12.58	12.56	7.14	9.23

ABTG- Advancing bitter gourd

The measurements of vine length at final harvest within the bitter gourd germplasm exhibited a spectrum extending from 213 cm to 371 cm, yielding a mean value of 283.29 cm. The germplasm 83-013 demonstrated a markedly elevated vine height at maturity (371 cm), with the subsequent germplasm variants such as 83-026 (346 cm), 83-023 (341 cm), ABTG-02 (340 cm) and 83-006 (340 cm) closely trailing behind. Conversely, germplasm 83-021 displayed a notably diminished vine height at maturity (213 cm).

The sex ratio within the bitter gourd germplasms exhibited a spectrum extending from 16.05 to 24.44, yielding a calculated mean value of 20.43. The germplasm ABTG-10 exhibited a significantly lower sex ratio per individual plant (16.05), closely followed by the subsequent germplasm entries, specifically 83-012 (16.21) and 83-013 (16.61). In contrast, the germplasm 83-009 demonstrated the highest sex ratio per individual plant, resulting in a calculated mean of 24.44.

The observed variation in growth characteristics, yield parameters and seed traits among bitter gourd germplasm can be attributed to a confluence of genetic and environmental determinants, in addition to their interrelations. Growth characteristics, including days to anthesis of staminate and pistillate flowers, number of staminate and pistillate flowers, vine height and sex ratio dictated by the genetic framework of the germplasm. However, they are also significantly modulated by environmental factors such as ambient temperature, soil nutrient availability and moisture levels. The interactions between genotype and environment (G×E) are pivotal, as identical genotypes may display divergent growth responses under varying ecological conditions. (Pradhan *et al*., 2013, Thakur *et al*., 2013, Prasanth *et al*., 2020, Alhariri *et al*., 2021, Harshitha & Shyamalamma, 2021 and Tanvi *et al*., 2021).

Yield Attributes

The number of fruits per plant within the bitter gourd germplasm exhibited a spectrum extending from 10.26 to 12.84, yielding a calculated mean value of 11.61.The germplasm 83-012 exhibited a markedly elevated quantity of fruits per individual plant (12.84), closely succeeded by the germplasm entries, namely 83-017 (12.73), 83-016 (12.47), 83-013 (12.46) and 83-005 (12.40). Conversely, the germplasm ABTG-09 manifested the lowest quantity of fruits per individual plant, culminating in a computed mean of 10.26.

The fruit length within the bitter gourd germplasm exhibited a rangefrom 12.76 cm to 29.75 cm, with a mean value of 22.33 cm. These findings highlighted the importance of selecting specific germplasm for breeding programmes aimed at optimizing fruit size and yield, which can ultimately enhance both marketability and nutritional value. The germplasm ABTG-03 exhibited a significantly higher fruits length (29.75 cm), closely succeeded by the entries, namely 83-006 (28.35 cm), ABTG-02 (28.16 cm), 83-026 (28.00 cm) and 83-023 (27.17 cm). Conversely, the germplasm 83-017 manifested the lowest fruit length (12.76 cm).

Significant variations were observed among the thirty germplasms with respect to the fruit diameter, fruit weight, number of seeds per fruits and fruit yield per plant (Table 3). The fruit diameter within the bitter gourd germplasm varied from 2.96 cm to 4.94 cm,

TABLE 3

Performance of bitter gourd genotypes for yield parameters *viz.*, fruit diameter, fruit weight, number of seeds per fruit and fruit yield per plant

Germplasm	Fruit diameter (cm)	Fruit weight (g)	Number of seeds per fruit	Fruit yield per plant (kg)
ABTG-01	3.64	109.24	19.27	1.16
ABTG-02	3.31	129.78	22.53	1.42
ABTG-03	3.83	161.78	25.67	1.90
ABTG-05	3.13	110.64	25.40	1.22
ABTG-06	3.66	103.58	14.67	1.09
ABTG-07	4.43	147.11	25.67	1.72
ABTG-08	4.23	110.38	12.13	1.30
ABTG-09	3.95	105.84	23.00	1.08
ABTG-10	3.53	120.98	29.13	1.45
83-001	3.55	72.04	23.53	0.87
83-002	4.55	109.98	17.00	1.27

Continued....

TABLE 3 Continued....

Germplasm	Fruit diameter (cm)	Fruit weight (g)	Number of seeds per fruit	Fruit yield per plant (kg)
83-003	3.40	83.97	20.13	0.99
83-004	4.32	90.98	31.07	1.00
83-005	3.49	60.64	18.40	0.76
83-006	3.60	147.91	20.87	1.66
83-008	3.47	105.66	24.67	1.24
83-009	4.15	75.78	25.93	0.92
83-010	3.27	78.11	25.93	0.93
83-012	3.47	71.51	23.20	0.93
83-013	2.96	112.91	17.33	1.41
83-014	3.93	102.38	22.80	1.13
83-015	4.94	122.24	14.40	1.41
83-016	3.44	94.04	27.67	1.18
83-017	3.54	65.51	27.33	0.85
83-019	3.62	120.91	33.67	1.37
83-021	4.31	135.84	23.93	1.60
83-023	3.71	126.58	23.00	1.53
83-024	4.55	133.18	17.53	1.56
83-026	3.27	115.98	24.00	1.23
83-029	3.98	128.51	23.13	1.46
Mean	3.77	108.47	22.77	1.25
S.Em±	0.08	4.26	0.52	0.07
CD at 5 %	0.22	12.05	1.48	0.19
CV (%)	3.53	6.80	3.98	9.47

ABTG- Advancing bitter gourd

with an average of 3.77 cm. The germplasm 83-015 demonstrated a significantly higher fruit diameter (4.84 cm), closely followed by 83-002, 83-024 (4.55 cm) and ABTG-07 (4.43 cm). In contrast, the germplasm 83-013 exhibited the lowest fruit diameter, (2.96 cm).

The fruit weight within the bitter gourd germplasm ranged 60.64 g to 161.78 g, yielding a calculated mean value of 108.47 g. The germplasm ABTG-03 demonstrated a markedly elevated fruit weight (161.78 g), closely followed by the subsequent germplasm entries, specifically 83-006 (147.91 g), ABTG-07 (141.11 g), 83-021 (135.84 g) and 83-024 (133.18 g). In contrast, the germplasm 83-005 exhibited the lowest fruit weight, (60.64 g).

The number of seeds per fruit within the bitter gourd germplasm exhibited a spectrum extending from 12.13 to 33.67, yielding a calculated mean value of 22.77. The germplasm 83-019 demonstrated a significantly increased number of seeds per individual fruit (33.67), closely followed by the germplasm entries, specifically 83-004 (31.07), ABTG-10 (29.13), 83-016 (27.67) and 83-017 (27.33). In contrast, the germplasm ABTG-08 exhibited the lowest number of seeds per individual fruit, resulting in a calculated mean of 12.13.

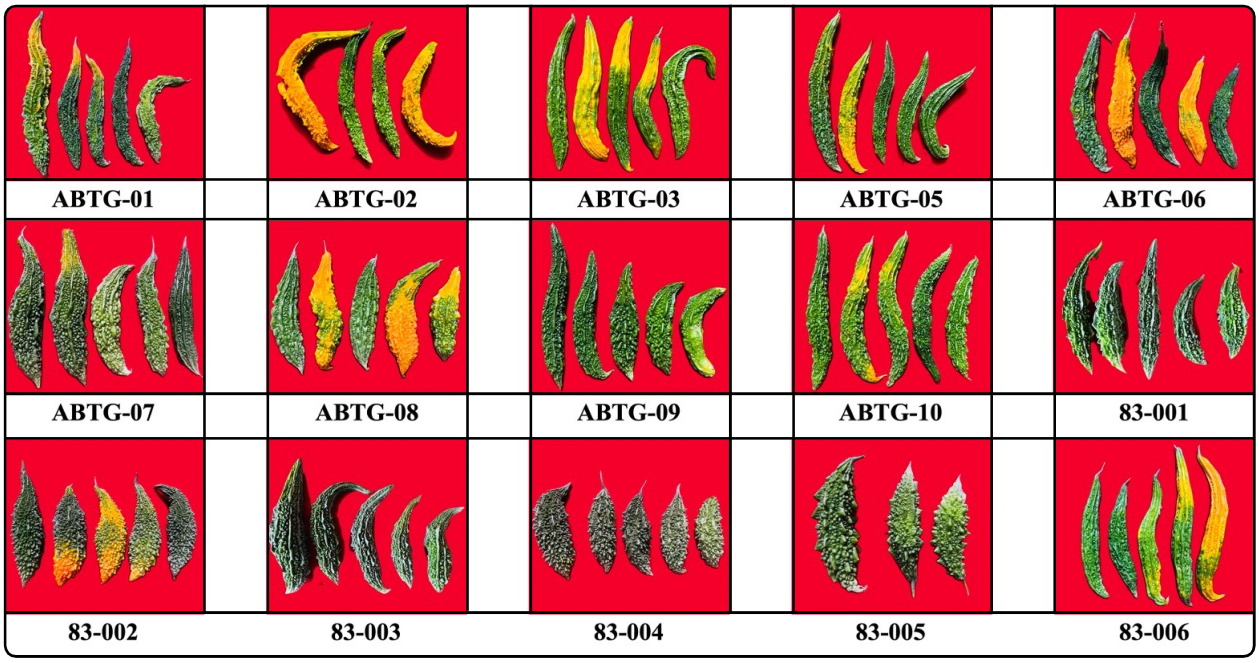

Plate 1 (A) : Diversity in fruit morphology among bitter gourd germplasm used in the study

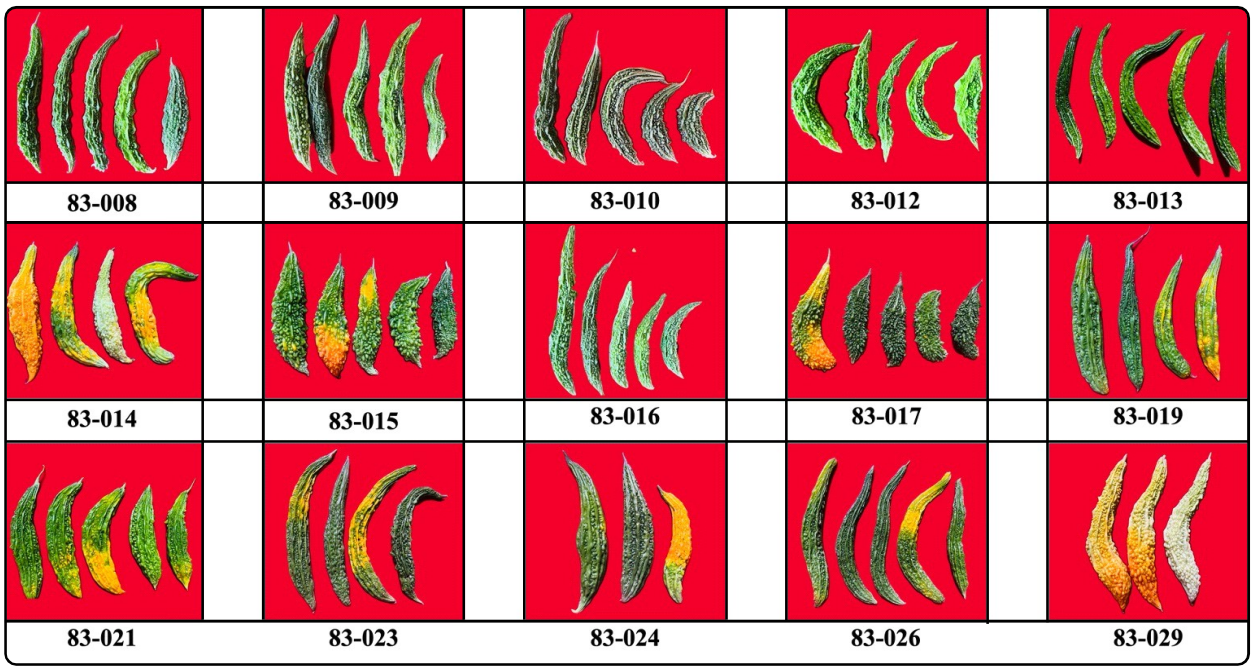

Plate 1 (B) : Diversity in fruit morphology among bitter gourd germplasm used in the study

Significant variations were observed among the thirty germplasm with respect to the fruit yield per plant (kg) (Table 3 and Fig. 2). The fruit yield per plant within the bitter gourd germplasm exhibited a spectrum extending from 0.76 kg to 1.90 kg, yielding a calculated mean value of 1.25 kg. The germplasm ABTG-03 demonstrated a significantly higher fruit yield per plant (1.90 kg),

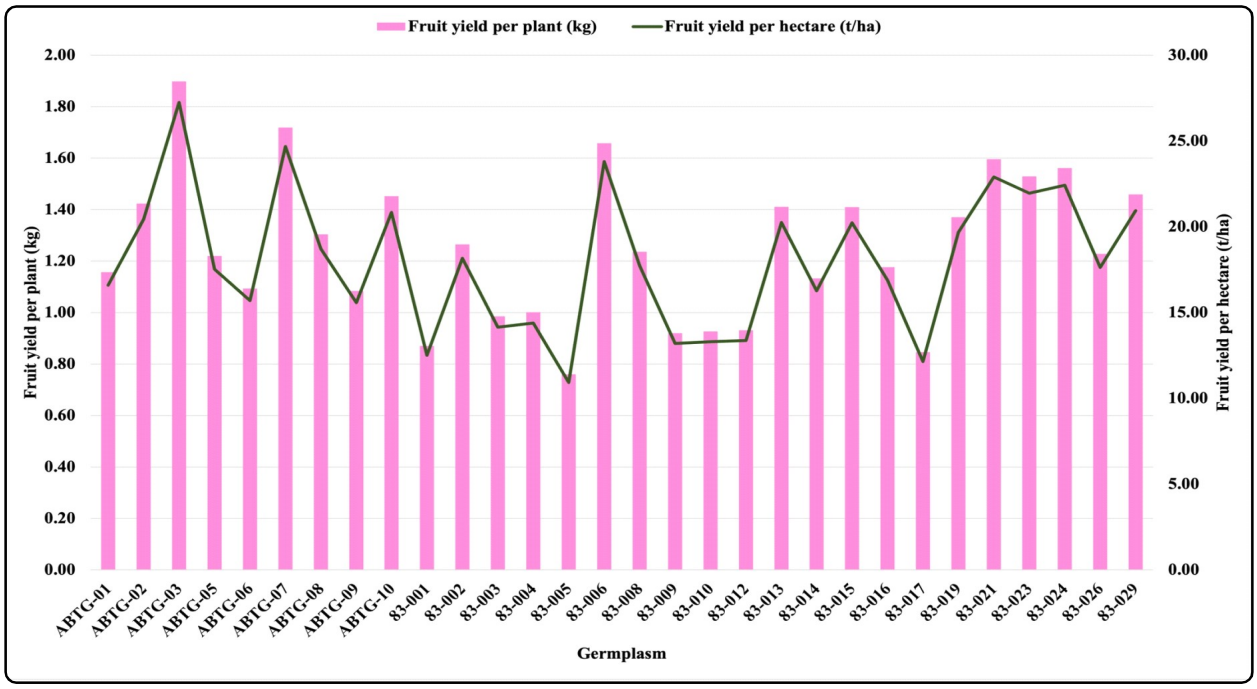

Fig. 2 : Fruit yield per plant (kg) and fruit yield per hectare (t/ha) in bitter gourd germplasm

closely followed by the subsequent germplasm entries, specifically ABTG-07 (1.72 kg), 83-006 (1.66 kg), 83-021 (1.60 kg) and 83-024 (1.56 kg). In contrast, the germplasm 83-005 exhibited the lower fruit yield per plant, resulting in a calculated mean of 0.76 kg.

Significant variations were observed among the thirty germplasm with respect to the fruit yield per hectare, seed yield per plant and per hectare (Table 4 and Fig. 2). Fruit yield per hectare within the bitter gourd germplasm exhibited a spectrum extending from 10.92 t/ha to 27.26 t/ha, yielding a calculated mean value of 18.01 t/ha. The germplasm ABTG-03 demonstrated a significantly higher fruit yield per hectare (27.26 t/ha), closely followed by the subsequent germplasm entries, specifically ABTG-07 (24.68 t/ha) and 83-006 (23.80 t/ha). In contrast, the germplasm 83-005 exhibited the lower fruit yield per hectare, resulting in a calculated mean of 10.92 t/ha.

The seed yield per plant within the bitter gourd germplasm exhibited a spectrum extending from 29.70 g to 121.13 g, yielding a calculated mean value of 61.56 g. The germplasm 83-029 demonstrated a significantly higher seed yield per plant (121.13 g), closely followed by the subsequent germplasm entries, specifically 83-026 (105.37 g), ABTG-05 (105.05 g), 83-010 (93.53 g) and 83-012 (78.13 g). In contrast, the germplasm ABTG-08 exhibited the lower seed yield per plant, resulting in a calculated mean of 29.70 g.

The seed yield per hectare within the bitter gourd germplasm exhibited a spectrum extending from 4.26 q/ha to 17.39 q/ha, yielding a calculated mean value of 8.84 q/ha. The germplasm 83-029 demonstrated a significantly higher seed yield per hectare (17.39 q/ha), closely followed by the subsequent germplasm entries, specifically 83-026 (15.13 q/ha) and ABTG-05 (15.08 q/ha). In contrast, the germplasm ABTG-08 exhibited the lower seed yield per hectare, resulting in a calculated mean of 4.26 q/ha.

Yield parameters demonstrate variability arising from the synergistic effects of genetic diversity, physiological efficiency and reproductive strategies.

Table 4

Performance of bitter gourd genotypes for yield parameters *viz.*, fruit yield per ha, seed yield per plant and per ha

Germplasm	Fruit yield per ha (t/ha)	Seed yield per plant (g)	Seed yield per ha (q/ha)
ABTG-01	16.60	41.05	5.89
ABTG-02	20.44	41.85	6.01
ABTG-03	27.26	51.94	7.46
ABTG-05	17.52	105.05	15.08
ABTG-06	15.70	32.59	4.68
ABTG-07	24.68	70.21	10.08
ABTG-08	18.72	29.70	4.26
ABTG-09	15.57	40.58	5.82
ABTG-10	20.84	77.62	11.14
83-001	12.50	61.68	8.85
83-002	18.17	37.87	5.44
83-003	14.16	41.24	5.92
83-004	14.39	56.54	8.12
83-005	10.92	53.72	7.71
83-006	23.80	54.30	7.79
83-008	17.74	70.92	10.18
83-009	13.20	73.77	10.59
83-010	13.31	93.53	13.43
83-012	13.38	78.13	11.22
83-013	20.25	48.74	7.00
83-014	16.26	56.30	8.08
83-015	20.24	31.47	4.52
83-016	16.90	72.68	10.43
83-017	12.15	55.64	7.99
83-019	19.68	78.95	11.33
83-021	22.91	65.41	9.39
83-023	21.95	58.94	8.46
83-024	22.43	39.95	5.73
83-026	17.64	105.37	15.13
83-029	20.95	121.13	17.39
Mean	18.01	61.56	8.84
S.Em±	0.98	4.35	0.62
CD at 5 %	2.79	12.32	1.77
CV (%)	9.47	12.24	12.24

ABTG- Advancing bitter gourd

As a cross-pollinated species, bitter gourd undergoes natural outcrossing facilitated by insect pollinators, thereby increasing heterozygosity and leading to pronounced yield variability among different germplasm. Additionally, disparities in photosynthetic efficiency, source-sink dynamics and the distribution of assimilates substantially influence the variability in yield-associated traits (Rai *et al*., 2008, Kole, 2007, Pandey & Prakash, 2019 and Ganavi *et al*., 2025).

Seed Attributes

Significant variations were observed among the thirty genotypes with respect to the seed size (mm^2), seed density, seed coat thickness and husk to kernel ratio (Table 5). The seed size within the bitter gourd germplasm exhibited a spectrum extending from 70.88 mm^2 to 112.14 mm^2, yielding a calculated mean value of 88.23 mm^2. The germplasm 83-015 demonstrated a significantly higher seed size (112.14 mm^2), closely followed by the subsequent germplasm entries, specifically ABTG-09 (106.57 mm^2), ABTG-06 (104.46 mm^2), 83-016 (99.41 mm^2) and ABTG-02 (98.13 mm^2). In contrast, the germplasm 83-026 exhibited the lower seed size, resulting in a calculated mean of 70.88 mm^2.

Seed density within the bitter gourd germplasm exhibited a spectrum extending from 0.15 g/cc to 0.73 g/cc, yielding a calculated mean value of 0.32 g/cc. The germplasm 83-029 demonstrated a significantly higher seed density (0.73 g/cc), closely followed by the subsequent germplasm entries, specifically 83-026 (0.70 g/cc), ABTG-05 (0.52 g/cc), 83-010 (0.49 g/cc) and 83-008 (0.42 g/cc). In contrast, the germplasm 83-015 exhibited the lower seed density (0.15 g/cc).

The seed coat thickness within the bitter gourd germplasm exhibited a spectrum extending from 0.36 mmto 0.75 mm, yielding a calculated mean value of 0.50 mm. The germplasm 83-026 demonstrated a significantly higher seed coat thickness (0.75 mm), closely followed by the subsequent germplasm entries, specifically 83-019 (0.67 mm), ABTG-03 (0.65 mm), ABTG-06

TABLE 5

Performance of bitter gourd genotypes for yield parameters *viz.*, seed size (mm^2), seed density (g/cc), seed coat thickness (mm) and husk to kernel ratio (%)

Germplasm	Seed size (mm^2)	Seed density (g/cc)	Seed coat thickness (mm)	Husk to kernel ratio (%)
ABTG-01	91.54	0.23	0.54	0.95
ABTG-02	98.13	0.18	0.45	0.54
ABTG-03	88.12	0.23	0.65	0.39
ABTG-05	86.06	0.52	0.54	0.58
ABTG-06	104.46	0.22	0.61	0.56
ABTG-07	80.57	0.39	0.42	0.52
ABTG-08	96.37	0.26	0.53	0.55
ABTG-09	106.57	0.16	0.49	0.62
ABTG-10	88.37	0.27	0.47	0.55
83-001	90.38	0.28	0.47	0.51
83-002	90.79	0.25	0.44	0.59
83-003	92.66	0.29	0.50	0.57
83-004	79.84	0.26	0.57	0.56
83-005	75.12	0.31	0.52	0.63
83-006	85.63	0.30	0.60	0.65
83-008	84.66	0.42	0.38	0.60
83-009	88.44	0.40	0.42	0.54
83-010	93.75	0.49	0.42	0.55
83-012	86.39	0.40	0.45	0.51
83-013	76.88	0.35	0.58	0.63
83-014	83.27	0.27	0.45	0.64
83-015	112.14	0.15	0.46	0.63
83-016	99.41	0.22	0.44	0.46
83-017	89.36	0.20	0.51	0.53
83-019	85.23	0.28	0.67	0.34
83-021	89.57	0.25	0.39	0.47
83-023	74.89	0.30	0.55	0.51
83-024	73.82	0.26	0.36	0.51
83-026	70.88	0.70	0.75	0.47
83-029	83.61	0.73	0.51	0.67
Mean	88.23	0.32	0.50	0.56
S.Em±	0.45	0.01	0.01	0.02
CD at 5 %	1.26	0.03	0.03	0.05
CV (%)	0.87	5.18	3.99	5.09

ABTG- Advancing bitter gourd

(0.61 mm) and 83-006 (0.60 mm). In contrast, the germplasm 83-024 exhibited the lower seed coat thickness (0.36 mm).

The husk to kernel ratio within the bitter gourd germplasm exhibited a spectrum extending from 0.34 to 0.95 per cent, yielding a calculated mean value of 0.56 per cent. The germplasm ABTG-01 demonstrated a significantly higher husk to kernel ratio (0.95 %), closely followed by the subsequent germplasm entries, specifically 83-029 (0.67 %), 83-006 (0.65 %), 83-014 (0.64 %), 83-005, 83-013 and 83015 (0.63 %). In contrast, the germplasm 83-019 exhibited the lower husk to kernel ratio of 0.34 per cent.

In accordance with the Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA) guidelines, thirty distinct bitter gourd germplasm were characterized based on seed morphology and systematically classified into different categories. Based on seed surface texture, the germplasm was grouped into rough and smooth types, while seed coat pigmentation enabled their classification into three distinct categories, namely brown, dark brown and light brown. Additionally, considering the degree of indentation along the seed margin, the germplasm wasfurther categorized into three groups, specifically small, medium and large (Table 6).

Among the thirty germplasm, twenty-six exhibited a rough texture (ABTG-01, ABTG-02, ABTG-03, ABTG-05, ABTG-06, ABTG-07, ABTG-08, ABTG-09, ABTG-10, 83-001, 83-005, 83-006, 83-008, 83-009, 83-010, 83-012, 83-013, 83-014, 83-015, 83-017, 83-019, 83-021, 83-023, 83-024, 83-026 and 83-029), whereas four germplasm displayed a smooth texture (83-002, 83-003, 83-004 and 83-016).

Within the cohort of thirty germplasm, fourteen were identified as exhibiting a brown hue (ABTG-01, ABTG-02, ABTG-06, ABTG-07, ABTG-08, 83-003, 83-004, 83-005, 83-010, 83-012, 83-019, 83-021, 83-023 and 83-026), while ten germplasm were characterized by a dark brown pigmentation

Table 6

Seed texture, seed colour and seed: indentation of margin in bitter gourd germplasm

Germplasm	Seed texture	Seed colour	Seed: Indentation of margin
ABTG-01	Rough	Brown	Small
ABTG-02	Rough	Brown	Small
ABTG-03	Rough	Dark brown	Medium
ABTG-05	Rough	Light brown	Small
ABTG-06	Rough	Brown	Medium
ABTG-07	Rough	Brown	Small
ABTG-08	Rough	Brown	Small
ABTG-09	Rough	Light brown	Small
ABTG-10	Rough	Light brown	Small
83-001	Rough	Dark brown	Medium
83-002	Smooth	Dark brown	Medium
83-003	Smooth	Brown	Small
83-004	Smooth	Brown	Large
83-005	Rough	Brown	Medium
83-006	Rough	Dark brown	Medium
83-008	Rough	Dark brown	Medium
83-009	Rough	Light brown	Medium
83-010	Rough	Brown	Small
83-012	Rough	Brown	Medium
83-013	Rough	Light brown	Small
83-014	Rough	Dark brown	Small
83-015	Rough	Dark brown	Medium
83-016	Smooth	Dark brown	Medium
83-017	Rough	Light brown	Large
83-019	Rough	Brown	Medium
83-021	Rough	Brown	Small
83-023	Rough	Brown	Small
83-024	Rough	Dark brown	Small
83-026	Rough	Brown	Small
83-029	Rough	Dark brown	Small

ABTG- Advancing bitter gourd

(ABTG-03, 83-001, 83-002, 83-006, 83-008, 83-014, 83-015, 83-016, 83-024 and 83-029) and six germplasm demonstrated a light brown coloration (ABTG-05, ABTG-09, ABTG-10, 83-009, 83-013 and 83-017).

Among the thirty evaluated germplasm, sixteen demonstrated a small indentation of margin of seed (ABTG-01, ABTG-02, ABTG-05, ABTG-07, ABTG-08, ABTG-09, ABTG-10, 83-003, 83-010, 83-013, 83-014, 83-021, 83-023, 83-024, 83-026 and 83-029), twelve germplasm revealed a medium seed: indentation of margin (ABTG-03, ABTG-06, 83-001, 83-002, 83-005, 83-006, 83-008, 83-009, 83-012, 83-015, 83-016 and 83-019), while two germplasm displayed a large seed: indentation of margin (83-004 and 83-017).

The disparity in seed attributes within bitter gourd germplasm is predominantly attributable to genetic variations influencing embryo maturation, seed coat morphology and the efficiency of nutrient distribution. Additionally, factors such as fruit dimensions, plant robustness and the environmental contexts in which seed development transpires play a significant role in this variability, thereby rendering it a critical characteristic in the selection for seed quality and propagation methodologies (Joshi *et al*., 1993, Sivaraj & Pandravada, 2005, Mladenovic *et al*., 2012, Ajuru & Okoli, 2013, Pradhan *et al.,* 2013, Mashilo *et al*., 2016, Buthelezi *et al*., 2019 and Sari *et al*., 2021).

In summary, the interplay of genetic diversity, G×E interactions, the propensity for cross-pollination and varying selection pressures collectively account for the substantial variation evident in the growth, yield and seed characteristics of bitter gourd germplasm. This variability is critically significant for breeding initiatives, as it provides an extensive foundation for the selection of superior genotypes endowed with desirable horticultural and seed quality attributes.

References

Ajuru, M. G. and Okoli, B. E., 2013, The morphological characterization of the melon species in the family Cucurbitaceae Juss. and their utilization in Nigeria. *Int. J. Mod. Bot.*., **3** (2) : 15 - 19.

Alhariri, A., Behera, T., Jat, G., Devi, M., Boopalakrishnan, G., Hemeda, N., Teleb, A., Ismail, E. and Elkordy, A., 2021, Analysis of genetic diversity and population structure in bitter gourd (*Momordica charantia* L.) using morphological and SSR markers. *Plants*, **10**.

Buthelezi, L. G., Mavengahama, S. and Ntuli, N. R., 2019, Morphological variation and heritability studies of *Lagenaria siceraria* landraces from northern KwaZulu-Natal, South Africa. *Biodiversitas*, **20** (3) : 922 - 930.

Ganavi, B., Yashwanth, C., Mahesh, H. and Harinikumar, K., 2025, Analysis of morphological diversity in traditional and improved rice varieties. *Mysore J. Agric. Sci*., **59** (2).

Harshitha, C. K. and Shyamalamma, S., 2021. Morphological characterization of local cucumber (*Cucumis sativus* L.) genotypes for fruit quality traits. *Mysore J. Agric. Sci.*, **55** (4).

Heiser, C. B., 1979, The Hourd Book. Univ. Oklahoma Press, Norman.

Jeffrey, C., 1967, The cucurbitaceae of eastern Asia, Malaysia and Australia. *Kew Bull.*, **20** : 417 - 426.

Joshi, D. C., Das, S. K. and Mukherjee, R. K., 1993, Physical properties of pumpkin seeds. *J. Agric. Eng. Res.*, **54** (3) : 219 - 229.

Kole, C. (Ed.), 2007, Vegetables, Vol. 5, Springer Science & Business Media, Dordrecht, Netherlands.

Laxuman, 2005, Studies on diversity, heterosis and combining ability in bitter gourd (*Momordica charantia* L.). M.Sc. (Agri.) Thesis, *Univ. Agric. Sci., Dharwad*, India.

Mashilo, J., Shimelis, H. and Odindo, A., 2016, Genetic diversity of bottle gourd (*Lagenaria siceraria* (Molina) Standl.) landraces of South Africa assessed by morphological traits and SSR markers. *S. Afr. J. Plant Soil*., **33** (2) : 113 - 124.

MLADENOVIC, E., BERENJI, J., OGNJANOV, V., LJUBOJEVIC, M. AND CUKANOVIC, J., 2012, Genetic variability of bottle gourd *Lagenaria siceraria* (Mol.) Standley and its morphological characterization by multivariate analysis. *Arch. Biol. Sci.*, **64** (2) : 573 - 583.

PANDEY, S. AND PRAKASH, V., 2019, Characterization of bitter gourd (*Momordica charantia* L.) germplasm for seed traits. *J. Pharmacogn. Phytochem*., **8** (5) : 191 - 195.

PRADHAN, R. C., SAID, P. P. AND SINGH, S., 2013, Physical properties of bottle gourd seeds. *Agric. Eng. Int.: CIGR J*., **15** (1) : 106 - 113.

PRASANTH, C. N., PITCHAIMUTHU, M., RAJ, N. S., PRASATH, D. AND DORAISWAMY, S., 2020, Evaluation of bitter gourd (*Momordica charantia* L.) genotypes for yield and yield-related traits. *J. Pharmacogn. Phytochem*., **9** (5) : 2299 - 2303.

RAI, M., PANDEY, S. AND KUMAR, S., 2008, Bitter Gourd (*Momordica charantia* L.). In: Rai, M. and Pandey, S. (Eds.). Vegetables: Genetic Resources and Improvement. New India Publishing Agency, New Delhi, 190 - 210.

SARI, N., SILVERMAN, E., REILAND, D. AND WEHNER, T. C., 2021, Seed characterization and relationships between seed and cotyledon properties in *Lagenaria* spp. accessions. *Hort. Sci*., **56** (2) : 185 - 192.

SIVARAJ, N. AND PANDRAVADA, S. R., 2005, Morphological diversity for fruit characters in bottle gourd germplasm from tribal pockets of Telangana region of Andhra Pradesh, India. *Asian Agrihist*., **9** (4) : 305 - 310.

SUNDARARAJ, N., NAGARAJU, S., VENKATARAMAN, M. N. AND JAGANATH, M. K., 1972, Design and analysis of field experiments. *Univ. Agric. Sci., Bengaluru*, 165.

TANVI, MEHTA, DUHAN, D. S. AND PANGHAL, V. P. S., 2021, Genetic diversity studies for improved horticultural traits in bitter gourd (*Momordica charantia* L.) genotypes. *Veg. Sci.*, **48** (2) : 198 - 202.

THAKUR, P., SHARMA, D., VISEN, V. K. AND DASH, S. P., 2013, Evaluation of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] genotypes. *Plant Arch.*, **15** (2) : 1037 - 1040.