

RESEARCH ARTICLE

# Morphological Characterization and Trait-Based Assessment of Bitter gourd (*Momordica charantia* L.) Genotypes under the Garhwal Hills

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## ABSTRACT

This experimental study was conducted to evaluate morphological variation and the Distinctness, Uniformity, and Stability (DUS) traits in bitter gourd (*Momordica charantia* L.) strains. It is a highly valuable cucurbit crop for its medicinal and nutritional richness. Any successful breeding program relies on robust and vast genetic diversity; this research experiment consists of 24 distinct lines collected from different parts of India. All the strains were grown in a Randomized Block Design (RBD) with three replications. The key observation related to morphological traits recorded from the selected plants in each treatment per replication. Findings indicated that all the strains exhibited a vast amount of genetic diversity across different traits. This variation has potential for use in future improvement programs.

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## INTRODUCTION

Cucurbit is one of the most diverse and iconic group of vegetables, which offers huge spectrum of variation from growth habit, sex forms, chromosome numbers, medicinal ability, purpose of uses, nutritional values etc., At the same time, the cucurbits become smaller in size than other vegetable crops in terms of area, production and marketing values all over the world (Priyadarshiniet. al., 2018). The family Cucurbitaceae comprises more than 30 genera & 750 species worldwide (Jeffrey, 1980). These species are well distributed in the New World as well as in the New World tropics; from an Indian context, 117 genera & 100 species have also been documented (Haldhar et al., 2018). Cucurbits are warm-season

crops, generally of tropical origin, primarily from the African centre, Tropical America, and Southeast Asia. The cucurbits thrive in these climatic conditions (Rajaaguru et al., 2019). Among the group of cucurbits, bitter gourd (*Momordica charantia* L.) is the focal point for its economic and medicinal value in both the traditional and new-era medicine fields. Bitter gourd is known by various names, including African cucumber, bitter cucumber, bitter melon, and balsam pear (Heiser, 1979). The genus *Momordica* includes more than 25 species in Africa alone, and it originated near Tropical Asia, particularly in eastern India and southern China (Laxuman, 2005). Basically in India, bitter gourd is grouped in two botanical varieties based

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on size & shape of fruits, surface texture and colour; one is appeared as a crocodile's back is botanically known as *M. charantia* var. *charantia*, another one is small round fruits with tubercles are botanically known as *M. charantia* var. *muricata* (Chakravarty, 2019) Bitter gourd is a hidden treasure of medicinal values for human races, it is well known for its purgative, anti-diabetic, anti-viral activity, *thermogenic*, tonic etc., the major medicinal properties of bitter gourd in current era is their anti-diabetic properties, which has been extensively studied and *hypoglycaemic* compound *charantin* has been isolated from bitter gourd (Jeffrey, 1980 and (Okabe et al., 1982). It has been used as a folk medicine for ages (Heiser, 1979). Bitterness in balsam pear is due to two major alkaloids, such as *cucurbitacin*-like alkaloid *momordicine* and *triterpene glycosides* (*momordicoside* K and L). The bitter gourd fruits are consumed as canned, parboiled, stuffed, stir-fried, dehydrated, and blanched. The increasing fame of bitter gourd as a natural health protector among consumers is a critical point for enhancing production and research and development efforts. The variation in morphology is the first visual sign of available variation in the germplasms. These signs come in the form of morphological changes, which might be small or large. These changes are the primary and essential component of the base of an improvemental program. The success of improvemental programs lies in the hands of the strategy maker and the amount of available variability in the germplasm. Technically, bitter gourd originated in Asia, so it represents a good amount of genetic variability across different parts of the country. From the breeder's point of view, for initiating and developing any breeding program, it is necessary to have access to the available genetic diversity and professional knowledge of crucial germplasms. The true-to-type cultivar expression gains very crucial values under the Protection of Plant Varieties and Farmers' Rights Act, 2001, through parameters outlined in the 'Minimal Descriptors of Vegetable Crops' for bitter gourd and guidelines from the International Union for the Protection of New Varieties of Plants. The Protection of Plant Varieties and Farmers' Rights (PPVFR) Act, 2001, is a driving force in the current era of crop improvement by mandating the Distinctiveness, Uniformity and Stability (DUS) testing. DUS testing serves as a first line of defense for the protection of intellectual property rights, the protection of breeder's interests, and the promotion of innovation

via Plant Variety Protection (PVP) systems. It is also very helpful in ensuring the uniformity, authenticity, and long-term stability of cultivars through a rigorous evaluation process. DUS testing provides another opportunity to determine whether a newly developed cultivar is actually distinct from existing ones within the same species, and it is also helpful in preventing excess among gene bank accessions (Mahapatra et al., 2022; Mallikarjuna et al., 2023). Furthermore, data on genetic diversity for valuable important traits are invaluable for designing breeding strategies. Ongoing research in this field will guide the development of climate-resilient high-yielding varieties. Morphological parameters often vary among genotypes & between genotypes, and these differences might be heritable or non-heritable, underscoring the need for detailed studies on cultivated variability to generate baseline data. Such valuable information will validate varietal advantages and unlock more opportunities for crop improvement.

## MATERIALS AND METHODS

### *Experimental Site*

A research investigation was carried out under field conditions during the Zaid season, 2022, at the Horticultural Research Center (HRC), Chauras Campus, Department of Horticulture, H.N.B. Garhwal University, Srinagar (Garhwal), Uttarakhand, India. The experimental site is located in the middle of the Alaknanda Valley, at a longitude of 78° 47' 30" E and a latitude of 30° 13' 0" N, with an elevation of 540 meters above MSL, in the Garhwal region of Uttarakhand. The experimental site falls under subtropical conditions, characterized by harsh weather during the summer season (April to June), with the mercury reaching up to 40 °C. On the other hand, during winter months, especially (December to mid-January) mercury falls below 4 °C. The textural class of the experimental field is sandy loam, with a pH of 6.4; the soil contains 0.84% organic carbon, 95.30 kg per hectare available nitrogen, 3.05 kg available phosphorus, and 135.0 kg per hectare available potassium.

### *Experimental Design and Materials Used*

This research experiment utilized 24 genotypes of bitter gourd (*Momordica charantia* L.), selected for their potential in various economically important traits as well as available genetic diversity in the genotypes. The research experiment was laid out in a

Complete Randomized Block Design (RCBD) with three replications, which is essential to reduce experimental error. The list of germplasms with their resource is presented in Table 1.

**Preparation of Media and Sowing of Seeds**

For preparing the media, well-decomposed FYM and soil were thoroughly mixed in a 1:1 ratio. Before mixing, both components were sieved to remove unwanted materials, including weeds, debris from previous-year plant parts, stones, pebbles, and other non-essential materials. The media was firmly filled into poly bags, leaving a maximum of 1 inch of space at the top of the poly bag. The seeds of every genotype were sown individually in poly bags. Just after sowing, a light watering was applied to ensure optimal moisture for good & uniform germination. All necessary precautions were taken to ensure the healthy development of the seedlings.

**Field and Bed Preparation**

Firstly, the research field was deep-plowed, then harrowed three times to achieve maximum tilth, followed by planking 17 days before the transplanting of seedlings. During the research field preparation, removed all unwanted materials, such as weeds, debris from previous-year plant parts, stones, pebbles, and other non-essential materials. The experimental field was demarcated with the help of a rope, measuring tape, marking sticks, a hoe, and a shovel. The experimental field was divided into four blocks; each block consisted of 18 plots, each measuring 6.0

× 4.0 m. Fifteen days before the transplantation of genotypes, fully decomposed organic manure (FYM) @ 25 t/ha was applied to ensure the availability of all essential nutrients at the right time. On the other side, the recommended dose @80N:50P:50K kg/ha was used in the form of urea, DAP, and SSP before the transplanting of the crop at the same time, a full dose of phosphorus, potassium and half dose of nitrogen were applied before transplanting the remaining dose of nitrogen use in split doses to maximize the efficiency of fertilizer.

**Transplanting**

The healthy, well-developed seedling was transplanted at the four-leaf stage to maximize seedling establishment. The transplanting operation was carried out in the evening hours across the experimental field as per the layout plan. The row-to-row and plant-to-plant spacing is 1.50 x 1.0 m, recommended. Immediately after transplantation, light irrigation was applied to ensure the survival and establishment of all the genotypes.

**After care**

Standard intercultural operations are one of the most important aspects of any crop production. They ensure healthy crop growth and maximize the utilization of all resources, which is beneficial for optimizing the yield. The initial two weeding operations are crucial for suppressing crop-weed competition. Irrigation is another aspect of good crop production. Irrigation was applied as needed to meet crop requirements.

**Table 1. List of genotypes used in research work along with their resources**

Sr. No.	Genotypes	Sources	Sr. No.	Genotypes	Sources
1	GP-1	Gorakhpur, U.P.	13.	SM-15	Sikkim
2	HP-1	Mandi, H.P.	14.	TN-1	Tamil Nadu
3	HP-2	Mandi, H.P.	15.	VRBTG-1	IIVR, Varanasi
4	JP-1	Jaunpur, U.P.	16.	VRBTG-2	IIVR, Varanasi
5	KVS-7	Pauri, U.K.	17.	VRBTG-3	IIVR, Varanasi
6	MN-1	Khurai, M.N.	18.	VRBTG-4	IIVR, Varanasi
7	MP-1	Jabalpur, M.P.	19.	VRBTG-5	IIVR, Varanasi
8	PDM	IIVR, Varanasi	20.	VRBTG-6	IIVR, Varanasi
9	PSPB-14	Imphal, M.N.	21.	VRBTG-7	IIVR, Varanasi
10	RAJ-1	Jaipur, Rajasthan	22.	VRBTG-8	IIVR, Varanasi
11	RAJ-2	Jaipur, Rajasthan	23.	VRBTG-9	IIVR, Varanasi
12	SM-13	Sikkim	24.	VRBTG-10	IIVR, Varanasi

### **Data Recorded**

In this field research, the trial was conducted to examine genetic variation and characterize strains for 29 morphological characters, which were scientifically recorded for each strain across different growth stages. All the observations were assessed in regulation with the guidelines of DUS test (PPV and FR Acts, 2001). All essential morphological traits examined during the DUS test included plant, reproductive, fruit, and seed characters. All the characters were recorded from the tagged plants at the specific stage of plant growth with the trait at full expression.

### **RESULTS AND DISCUSSION**

In this research investigation, 29 key parameters were analyzed for different plant aspects, including morphological characteristics of plants, leaves, fruits, and seeds (Table 2 and 3). Among these characters, six selected parameters were recognized as unalterable across 24 strains assessed. The coherent characters included the leaf blade margin, which was serrate and multifid; leaf blade shape, which was cordate and obovate; and leaf blade number, which was consistently observed at 5 lobes across all genotypes. The flower color was divided into light yellow to yellow across all the collected genotypes. The fruit shape base at the peduncle end, as well as the fruit shape of the apex at the blossom end, is distinct between the acute and obtuse groups in all the genotypes. In contrast, the rest of the characters showed a vast amount of variation across all the collected strains, reflecting inherent variation within the collected population. These different characters have been further regrouped based on their biological relevance, into three major groups: plant characteristics, fruit characteristics, and seed characteristics. This grouping is very helpful for the focused elaboration of the recorded morphological variation and its possible application to strain characterization and future breeding work.

#### **Plant Characteristics**

The color of the cotyledon was examined in all collected strains, revealing that 54.16% and 33.33% of the evaluated genetic materials showed a medium and dark color of the cotyledon, respectively. On the other hand, 12.15% (3 out of 24 strains) showed light color pigmentation in the cotyledon. The cotyledon color is not directly associated with yield-related traits. But it is very helpful for differentiating between genotypes due to pigmentation. The intensity of cotyledon color is also associated with the stress resistance potential

of strains. The major yield-associated characters, i.e., vine length, number of productive branches, and intermodal distance between fruiting nodes, were highly influenced by yield capability by increasing the number of flowers and number of fruits per plant, which ultimately manipulated the total yield. The length of the vine significantly influences its growing place; small, compact vines are most suitable for cultivation because their management practices are easy. In this research, only 4.16% of strains showed compact growth behavior, while the remaining genotypes grouped into the medium (66.66%) and tall (29.16%) classes. While a huge amount of genetic variation is recorded in the number of reproductive branches and inter-nodal distance among the strains. This finding is consistent with the conclusions of Jatav *et al.*, (2022) and Panigrahi *et al.*, (2024). The stem shape of bitter gourd was assessed among the collected strains; the result revealed that 70.83% of the evaluated strains showed an angular stem, while 29.16% displayed a round stem. The intermodal length is the major component of reproductive branches in the main stem. Internodes are the basic sites for primary branches, and primary branches harbor secondary branches; these internodes are the sites of flower emergence. The inter-node length of the main stem, measured between the 15<sup>th</sup> and 20<sup>th</sup> nodes, ranged from short (<5cm) to long (>8cm). Among the strains, only 8.33% strains showed the short inter-node distance, while the remaining (50.00%) strains had medium, and (41.66%) strains showed long inter-node distance. This variation in inter-nodal distance could be a major selection criterion for future breeding programs to create sophisticated plant architecture for higher yield. The distribution of primary branches in the (50%) collected strains is well proportional (10-20 branches) in the main stem, followed by 37.50% strains in many categories and 12.50% strains in the less group. Similar findings were reported by Jatav *et al.*, (2022). The leaf blade length was primarily medium (6-9cm), recorded in 54.16% of the strains, while (16.66%) strains displayed a long leaf blade (>9cm), and 12.50% in short leaf blade length. Leaf blade width was dominant; medium was observed in 45.83% of the strains, only eight strains (33.33%) showed broad leaf blade width, and 20.83% of the strains recorded narrow leaf blade width. The leaf blade margin observed in (87.50%) strains was multifid, while only (12.50%) displayed the serrate type. Similar

Table 2. Morphological characterization of Bitter gourd (*Momordica charantia* L.) genotypes based on various qualitative traits

Sr. No.	Genotypes	Cotyledon: intensity of green colour	Plant: main vine length	Stem: shape	Stem: length of internodes of main stem (between 15 <sup>th</sup> -20 <sup>th</sup> node)	Stem: number of primary branches	Leaf blade: length	Leaf blade: width	Leaf blade: margin	Leaf blade: shape	Leaf blade: number of lobes	Leaf blade: depth of lobing	Petiole: length	Flower: colour	Ovary: length (the of anthesis)
	GP-1	3	7	2	5	7	7	5	5	1	3	5	5	5	3
	HP-1	7	7	2	5	5	5	7	5	2	3	3	5	5	7
	HP-2	7	7	2	7	3	5	5	5	2	3	5	7	3	3
	JP-1	5	5	2	7	7	3	7	5	2	3	3	5	5	7
	KVS-7	5	5	2	7	5	5	5	3	2	3	5	7	5	5
	MN-1	5	5	2	5	7	5	5	5	2	3	5	5	3	5
	MP-1	5	7	2	5	7	3	3	5	2	3	5	3	3	7
	PDM	3	7	2	7	7	5	7	5	1	3	3	5	5	7
	PSPB-14	5	7	1	7	5	5	3	5	1	3	7	5	3	5
	RJ-1	5	5	1	5	7	5	5	5	2	3	5	5	3	5
	RJ-2	7	5	2	7	5	7	7	3	2	3	5	7	5	7
	SM-13	5	5	1	5	3	5	5	5	2	3	7	5	5	3
	SM-15	7	7	2	5	7	5	5	5	2	3	5	7	3	5
	TN-1	7	5	2	7	5	7	3	5	2	3	7	5	3	3
	VRBTG-1	5	5	1	7	5	5	5	3	2	3	7	5	3	5
	VRBTG-2	3	5	1	3	5	5	7	5	2	3	3	7	3	3
	VRBTG-3	7	5	2	7	5	5	7	5	2	3	7	5	3	5
	VRBTG-4	5	5	2	5	5	5	7	5	2	3	7	5	3	5
	VRBTG-5	7	5	2	7	7	3	5	5	2	3	5	5	3	5
	VRBTG-6	5	5	1	3	5	5	3	5	2	3	5	7	5	5
	VRBTG-7	5	5	2	5	5	5	7	5	1	3	7	7	5	5
	VRBTG-8	5	3	1	5	3	7	5	5	2	3	5	5	5	3
	VRBTG-9	5	5	2	5	5	5	3	5	2	3	5	5	5	5
	VRBTG-10	7	5	2	5	7	5	5	5	2	3	5	7	3	5
Status of Characteristics according to Minimal Descriptors of Vegetable Crops		Light-3 Medium-5 Dark-7	Short viny-3 Medium viny-5 Long viny-7	Rounded-1 Angular-2	Short-3 Medium-5 Long-7	Less-3 Medium-5 Many-7	Short-3 Medium-5 Long-7	Narrow-3 Medium-5 Broad-7	Entire-1 Serrate-3 Multifid-5	Obovate-1 Cordate-2 Oblong-3 Reniform-4	5 lobes-3 7 lobes-5	Shallow-3 Medium-5 Deep-7	Short-3 Medium-5 Long-7	Light yellow-3 Yellow-5 Deep yellow-7	Short-3 Medium-5 Long-7

Cont.....

Sr. No.	Genotypes	Fruit: length	Fruit: diameter	Peduncle: length	Fruit: color of skin at	Fruit: shape of base at peduncle end	Fruit: shape of apex at blossom end	Fruit: shape in longitudinal selection	Fruit: tubercles	Fruit: tubercles prominence	Fruit: ridge	Fruit: bitterness	Fruit: colour of skin at the ripe stage	Seed: colour	Seed: indentation of margin	Seed surface
1.	GP-1	7	7	5	4	2	1	3	5	2	2	3	3	1	5	3
2.	HP-1	5	5	5	5	1	1	3	5	2	2	3	2	3	5	5
3.	HP-2	9	5	7	1	1	1	1	5	1	2	3	2	2	5	3
4.	JP-1	5	7	5	1	2	2	2	5	2	1	5	3	1	3	3
5.	KVS-7	5	5	5	5	1	1	3	3	2	2	3	2	2	5	5
6.	MN-1	7	5	3	4	2	1	2	3	2	1	5	1	5	7	5
7.	MP-1	5	5	5	4	1	2	3	7	2	1	3	1	3	5	5
8.	PDM	3	5	3	5	1	1	3	5	2	2	3	2	3	3	5
9.	PSPB-14	5	7	5	6	1	2	3	7	2	2	3	3	2	3	3
10.	RJ-1	7	5	3	4	2	1	2	3	1	2	5	2	1	7	5
11.	RJ-2	5	7	5	6	1	1	1	5	2	2	3	2	3	5	5
12.	SM-13	5	7	5	4	2	2	2	7	2	2	3	1	2	5	5
13.	SM-15	5	5	7	1	2	1	3	7	1	1	5	3	2	7	3
14.	TN-1	5	5	5	4	2	2	2	5	2	2	3	2	1	5	5
15.	VRBTG-1	5	7	5	5	2	1	3	5	1	1	3	2	3	5	5
16.	VRBTG-2	3	5	3	3	1	1	3	3	2	2	3	2	5	7	5
17.	VRBTG-3	5	5	5	5	2	2	3	3	2	2	5	3	2	3	5
18.	VRBTG-4	5	5	3	4	2	1	3	5	1	2	3	2	1	5	5
19.	VRBTG-5	5	5	5	4	1	2	3	5	2	2	3	2	2	5	5
20.	VRBTG-6	7	7	5	5	2	1	2	5	1	1	5	2	2	5	5
21.	VRBTG-7	5	5	3	4	2	1	3	5	1	2	3	2	1	7	5
22.	VRBTG-8	5	7	5	4	1	2	2	5	2	2	3	2	2	7	3
23.	VRBTG-9	7	7	5	5	1	1	2	7	1	2	5	1	1	5	3
24.	VRBTG-10	5	5	5	6	1	2	3	5	2	1	3	2	2	5	5
	Status of Characteristics according to Minimal Descriptors of Vegetable Crops	Very short-1 Short-3 Medium-5, Long-7, Extra long-9	Thin-3, Medium-5 Thick-7	Short-3, Medium-5, Long-7	White-1, Creamy white-2, Light green-3, Green-4, Dark green-5 Glossy green-6	Acute-1, Obtuse-2 Rounded-3, Flattened-4	Acute-1, Obtuse-2 Rounded-3, Flattened-4	Oblong-1, Ovate-2, Spindle shaped-3, Club shape-4, Triangular-5	Absent-1, Few-3 Medium-5, Many-7	Conspicuous-1 Non-conspicuous-2	Discontinuous-1 Continuous-2	Mild-3 Strong-5	Yellow-1, Orange-2 Reddish orange-3 Black-5	Light brown-1, Brown-2 Dark brown-3, Yellow-4, Black-5	Small-3, Medium-5 Large-7	Smooth-3 Rough-5



**Table 3: Morphological characterization of Bitter gourd (*Momordica charantia* L.) genotypes based on descriptor-based qualitative traits.**

Characteristics	States	Note	Number of Genotypes	Frequency (%)
Cotyledon: intensity of green colour	Light	3	03	12.50
	Medium (GG-137d)	5	13	54.16
	Dark (GG-137a)	7	08	33.33
Plant: main vine length	Short viny (<2.0m)	3	01	4.16
	Medium viny (2-2.75m)	5	16	66.66
	Long viny (>2.75m)	7	07	29.16
Stem: shape	Rounded	1	07	29.16
	Angular	2	17	70.83
Stem: length of internodes of main stem (between 15 <sup>th</sup> -20 <sup>th</sup> node)	Short (<5cm)	3	02	8.33
	Medium (5-8cm)	5	12	50.00
	Long (>8cm)	7	10	41.66
Stem: number of primary branches	Less (<10)	3	03	12.50
	Medium (10-20)	5	12	50.00
	Many (>20)	7	09	37.50
Leaf blade: length	Short (<6cm)	3	03	12.50
	Medium (>6-9cm)	5	13	54.16
	Long (>9cm)	7	04	16.66
Leaf blade: width	Narrow (>6cm)	3	05	20.83
	Medium (6-10cm)	5	11	45.83
	Broad (>10cm)	7	08	33.33
Leaf blade: margin	Entire	1	00	00
	Serrate	3	03	12.50
	Multifid	5	21	87.50
Leaf blade: shape	Obovate	1	04	16.66
	Cordate	2	20	83.33
	Oblong	3	00	00
	Reniform	4	00	00
Leaf blade: number of lobes	5 lobes	3	24	100
	7 lobes	5	-	00
Leaf blade: depth of lobing	Shallow	3	04	16.66
	Medium	5	13	54.16
	Deep	7	07	29.16
Petiole: length	Short (<6cm)	3	01	4.16
	Medium (5-8cm)	5	15	62.50
	Long (>8cm)	7	08	33.33
Flower: colour	Light yellow YG-3a & 3b	3	14	58.33
	Yellow (YG-7d)	5	10	41.66
	Deep yellow	7	00	00
Ovary: length (on the time of anthesis)	Short (<1.50cm)	3	06	25.00
	Medium (1.5-2.5cm)	5	13	54.16
	Long (>2.5cm)	7	05	20.83



Cont.....

Characteristics	States	Note	Number of Genotypes	Frequency (%)
Fruit: length	Very short(<5cm)	1	00	00
	Short (5-10cm)	3	02	8.33
	Medium (10.1-15cm)	5	16	66.66
	Long (15.1-20cm)	7	05	20.83
	Extra long (>20cm)	9	01	4.16
Fruit: diameter	Thin (<3cm)	3	06	25.00
	Medium (3-4.5cm)	5	16	66.66
	Thick (>4.5cm)	7	02	8.33
Peduncle: length	Short (<5cm)	3	06	25.00
	Medium (5-10cm)	5	16	66.66
	Long (>10cm)	7	02	8.33
Fruit: colour of skin at	White	1	03	12.50
	Creamy white (142B)	2	00	00
	Light green (141C)	3	01	4.16
	Green (137C)	4	10	41.66
	Dark green (147C)	5	07	29.16
	Glossy green (143C)	6	03	12.50
Fruit: shape of base at peduncle end	Acute	1	12	50.00
	Obtuse	2	12	50.00
	Rounded	3	00	00
	Flattened	4	00	00
Fruit: shape of apex at blossom end	Acute	1	15	62.50
	Obtuse	2	09	37.50
	Rounded	3	00	00
	Flattened	4	00	00
Fruit: shape in longitudinal selection	Oblong	1	02	8.33
	Ovate	2	08	33.33
	Spindle shaped	3	14	58.33
	Club shape	4	00	00
	Triangular	5	00	00
Fruit: tubercles	Absent	1	00	00
	Few	3	05	20.83
	Medium	5	14	58.33
	Many	7	05	20.83
Fruit: tubercles prominence	Conspicuous	1	08	33.33
	Non-conspicuous	2	16	66.66
Fruit: ridge	Discontinuous	1	07	29.16
	Continuous	2	17	70.83
Fruit: bitterness	Mild	3	17	70.83
	Strong	5	07	29.16
Fruit: color of skin at the ripe stage	Yellow (YG-9C)	1	04	16.66
	Orange (OG-24a)	2	15	62.50
	Reddish orange (OG-N25a)	3	05	20.83



Count.....

Characteristics	States	Note	Number of Genotypes	Frequency (%)
Seed: colour	Light brown (GY-161A, B, C & GO-164B)	1	07	29.16
	Brown (GO-164A & GO-167C)	2	10	41.66
	Dark brown (GO-165B)	3	05	20.83
	Yellow	4	00	00
	Black	5	02	8.33
Seed: indentation of margin	Small	3	04	16.66
	Medium	5	10	41.66
	Large	7	06	25.00
Seed surface	Smooth	3	07	29.16
	Rough	5	17	70.83

finding was reported by Casas *et al.*, (2016). On the other side, cordate type leaf blade was dominant (83.33%) over other types of leaf blade, whereas only (16.66%) showed obovate type of leaf blade. Among the collected strains, the 5-lobed leaf blade numbers were predominant (100%) across all strains. The most efficient variation was determining leaf blade depth of lobing, ranging from medium to shallow. Whereas 54.16% of the strains displayed medium leaf blade of lobing, 7 strains (29.16%) showed deep leaf blade depth of lobing, and (16.66%) strains showed shallow lobing. The petiole length is one of the most valuable traits; the medium (5-8 cm) petiole length was dominant (62.50%), and 33.33% (8 out of 24 strains) displayed long petioles (>8 cm), while only 4.16% strains exhibited short petioles. Similar findings were reported by Casas *et al.*, (2016), Jatav *et al.*, (2022), and Panigrahi *et al.*, (2024).

**Flower and Fruit Related Characteristics**

The field experiment was conducted to examine the morphological characteristics associated with various flower and fruit-related traits. All the traits related to flowers and fruits are furnished in Tables 1 and 2. The bitter gourd is highly cross-pollinated and monoecious. The flower color is always very crucial in pollination. Light yellow-colored flowers are predominant (58.33%) in bitter gourd, while 41.66% strains produce yellow-colored flowers. The length of the ovary is a key character that showed its significance in the fruit development process. A similar result was reported by Choudhary *et al.*, (2015) and Dhillon *et al.*, (2016). The significant variation was observed in ovary length (at the day of anthesis), ranging from long to short. Whereas 54.16% strains come in the class of medium-sized ovary, the

25% strains displayed short ovary length. On the other hand, long ovary length was found in only 20.83% of strains. A notable diversity was observed in fruit length among the collected 24 bitter gourd strains, ranging from 5 to 20 cm. Out of 24 strains, 8.33% (02 strains) measured between 5-10cm, 66.66% (15 strains) measured in class 10-15cm, 20.83% (05 strains) measured in class between 15-20cm, and only 4.16% (01 strain) found in the class of >20cm. This result is consistent with the conclusions of Suma *et al.*, (2022) and Mallikarjuna *et al.*, (2024). The significant variation was reported in fruit diameter, from <3.0 to 4.50 cm. Most of the collected strains fall in the medium size class (66.66%), and 25% strains are in the category of thin fruit diameter, while the remaining (8.33%) are in the group of thick fruit diameter. Similar findings were reported by Dey *et al.*, (2010), Pandey *et al.*, (2019), and Rathod *et al.*, (2021). Medium fruit peduncle length (5-10cm) was predominant (66.66% of the collected strains), with 25% showing short peduncle length (<5cm) and 8.33% displaying long fruit peduncle length (>10cm). Regarding fruit skin color, the collected strains exhibited almost all colors, ranging from white to glossy green. Out of 24 strains, only 12.50% (02 strains) displayed white-colored fruits; one strain exhibited light green-skinned fruit. The maximum 41.66% (10 strains) in the class of green skin color, seven strains displayed dark green color, and the remaining strains fall in the category of glossy green skin color. The collected germplasm offers a huge opportunity in terms of fruit shape and color. This variability serves as a source for future breeding and selection programs. This result is consistent

with the conclusions of Suma *et al.*, (2022) and Mallikarjuna *et al.*, (2024).

The same extent of variation was observed in fruit shape at the apex of the blossom end: 58.33% of strains produced spindle-shaped fruit, 33.33% produced ovate-shaped fruit, while 8.33% contributed to the oblong shape of fruits. Similar results were reported by Pandey *et al.*, (2019). The fruit shape of base at peduncle end was distributed as 50% and 50% between acute and obtuse type fruit: shape of base at peduncle end, respectively. Similar findings were reported by Alhariri *et al.*, (2019). The significant variation in fruit shape was observed among the collected strains in this research. The fruit shape of apex at blossom end was dispersed as 62.50% and 37.50% between acute and obtuse types of fruits, respectively. No fruits fell in the class of rounded and flattened types of fruit shape. Similar findings were reported by Alhariri *et al.*, (2019). The majority (58.33%) of strains had medium fruit tubercles, whereas 20.83% of strains exhibited few fruit tubercles, and 20.83% strains displayed many fruit tubercles. This finding is consistent with the conclusions of Mallikarjuna *et al.*, (2024). Fruit tubercles were examined to be non-conspicuous in 66.66% of the strains, whereas 29.19% fall in the category of conspicuous fruit tubercles prominence. On the other hand, the 70.83% strains exhibited continuous fruit ridge, while 29.16% displayed discontinuous fruit ridge among the collected strains. The bitterness in bitter gourd is a medicinal property, which is utilized in various ways in both folk and modern medicine. From a bitterness point of view, a mild bitter fruit was found to be predominant in 70.83% of the strains, whereas 29.16% displayed strong bitter fruits. The color change is the first sign of seed maturity in bitter gourd fruits. The majority (62.50%) of strains had orange skin color, 20.83% had reddish-orange skin color, while only 16.66% had yellow skin color at the ripe stage.

### **Seed Characteristics**

In this field work, three key traits associated with seed characters, such as seed color, indentation of margin, and seed surface, were studied under this research investigation. All observations were recorded in accordance with DUS guidelines. All the examined observations related to seed characteristics are presented in Tables 1 and 2. In the collected strains, brown seed color was dominant, observed in 41.66% of the genotypes, 29.16% of the samples in the light

brown class, and the remaining 20.83% in the dark brown class. A significant variation was recorded in seed indentation of the margin, ranging from (25.00%) large to (16.66%) small. This result is consistent with the conclusions of Suma *et al.*, (2022) and Mallikarjuna *et al.*, (2024). The seed surface was found rough in 70.83% strains, whereas 29.16% exhibited a smooth surface.

### **CONCLUSION**

This experiment revealed a high degree of morphological diversity among the collected bitter gourd strains. The major variation was observed in various economically important traits, i.e., fruit length, fruit shape, fruit color, ridges, and related traits. All the collected strains exhibited a monoecious sex form, a continuous growth habit, and fertile pollen. The DUS descriptors are very useful for differentiating strain traits, providing an authentic and reliable basis for identification and registration under the PPV & FR Acts 2009. These findings establish very crucial baseline data for future breeding programs in bitter gourd.

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This study did not require ethical approval as it did not involve live human participants or animal subjects."

### **Originality and Plagiarism:**

We, the authors, hereby certify that the manuscript is an original research work and has not been previously published in any journal, book, or other media, in whole or in part.

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Vivek Singh conceptualized the research idea and data collection, Khulakpam Naseeruddin Shah data analysis, review and editing, Deepak Kumar Rana supervised and conceptualized the methodology, Nikhil Priyadarshi and Abhay Singh data collection.

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