

Research Article

Morphological characterization and yield performance of indigenous banana cultivars (*Musa* sp.) in Bangladesh in reference to geographical indicator (GI)

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ABSTRACT

In Bangladesh, bananas are the leading fruit crop, supplying more than 20% of total fruit production. This fruit was unique because of year-round availability, diversity, nutritious value, and consumer preference. More than 100 banana varieties are found in different parts of the country. Therefore, the morphological characterization of indigenous banana cultivars is especially significant in terms of geographical indication (GI). Thus, this research aims to characterize different cultivars of bananas facilitating GI protection of physical properties and plant genetic resources as part of variety development, economic growth, export and sustainable agricultural development. Fifty-five indigenous accessions were collected from different parts of the country, and their morphological features (e.g., colour, weight, length, diameter, presence of seed, yield) were compared. Significant variations were found among the collected accessions. More than 50% of the indigenous accession yielded more yield than popular commercial varieties, indicating good market value and export potential. The research findings could add significant insights for identifying indigenous banana cultivars for GI registration.

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INTRODUCTION

Bananas are among the most produced and consumed foods globally, constituting the fourth most important staple food commodity after rice, wheat, and maize. Banana (*Musa spp.* L.) is possibly the world's oldest cultivated tropical fruit, and it is one of the most important members of the *Musaceae* family (Kamal *et al.*, 2015, Saha *et al.*, 2021). Bananas are among the most produced and consumed foods globally (Fuller & Madella 2009) constituting the fourth most important staple food commodity, after rice, wheat, and maize (Huang, 2010, Evans *et al.*, 2020). The Food and

Agriculture Organization ranks banana as the world's fourth most important crop after the major cereals (FAO, 2022). In Asian and Pacific regions, bananas have great socio-economic significance. Available data indicate that between 2000 and 2021, global production of bananas grew at a compound annual rate of 3.8 per cent, reaching a record of 124.98 million tons in 2021, up from around 68.2 million tonnes in 2000 (FAO, 2022).

The volume of the global banana industry is USD 139 billion, which is expected to reach USD 160 billion in 2035 (Evans *et al.*, 2020, FAO, 2022). However, it is important to note that only 15 per cent of banana production is traded in

the international market; the rest is consumed locally, most importantly in large producing countries such as India, China, and Brazil, and in some African countries where bananas contribute largely to people's diets.

There are more than 1,000 varieties of bananas produced and consumed locally in the world, but the most commercialized is the Cavendish-type banana, which accounts for around 47 per cent of global production (Teixeira *et al.*, 2022). With the rising population, increased industrial use and modern processing, the global demand for bananas is estimated to be 180 million tons in 2035 (Evans *et al.*, 2020).

India is the world's leading producer of bananas, accounting for nearly 26.3% of the total production in 2020 (Scott, 2021). Other major producers were the Philippines, Ecuador, Indonesia, and Brazil, together accounting for 20% of the world's total bananas and plantains (Ploetz & Evans 2015, Varma & Bebbler 2019). Bangladesh ranks 14th position among the top 20 banana-producing countries in the world (Saha *et al.*, 2021). In 2021, 0.58 million tons of bananas (both desert and plantain type) were produced from 40,800 ha of land (BBS, 2022). Along with commercial farming, homesteads, roadside, pond dike, and other fallow land are used for the cultivation of different types of indigenous bananas.

In Bangladesh, banana is one of the economically important fruit crops grown both at homesteads and commercial farms (Munia *et al.*, 2019). It is the most essential fruit crop which shares about 20% of total fruit production with a 36% share in the area (BBS 2018). Among the fruits produced in the country, it stands at the first position and supplies 42% of the total fruit requirements in the country. Its financial return as a crop is higher compared to other fruits and field crops (Rubel *et al.*, 2019).

About 300 varieties of bananas are grown in different countries of the world, of which a vast majority have been growing in Asian, Indo-Malaysian and Australian tropics and are now widely found throughout the tropical and sub-tropical countries (Munia *et al.*, 2019). In Bangladesh, more than 100 varieties of banana are found (Kabir *et al.*, 2015, BBS 2018). Popular commercial varieties are Sagor, Sobri, Kobri, Chinichampa and mehersagor (Molla *et al.*, 2009). Major districts of cultivated bananas are Narsingdi, Gazipur, Tangail, Rangpur, Bogra, Natore, Pabna, Noakhali, Faridpur, Khulna in Bangladesh. Districts of wild-grown bananas are Sylhet, Moulvibazar, Netrokona, Rangamati, Khagrachhari, and Bandarban (Hossain, 2014; Prodhan *et al.*, 2017).

Morphological characterization is essential because it provides valuable insights into the physical structure, shape, size, yield potential, consumer preference, market value, and composition (de Jesus *et al.*, 2009; Anyasi *et al.*, 2015). It helps in varietal improvements, genetic research, germplasm conservation, biodiversity study and quality control (Reddy *et al.*, 2015). Biodiversity conservation has been a critical global issue in the context of rapid urbanisation, soil degradation, deforestation, and environmental changes (Tschardt *et al.*, 2012). To ensure sustainable food security and a resilient production system, indigenous crop varieties and plant species might play a pivotal role (Glamann *et al.*, 2017). However, comprehensive research on the morphological characterisation of indigenous banana cultivars collected from all regions of Bangladesh is very limited. A few location-specific research explored the

diversity of common banana cultivars (Akter *et al.*, 2013, Kamal *et al.*, 2014), however, their research focus was narrow.

Thus, this research aimed to conduct a detailed morphological characterization of the accessions for efficient management of the collection and utilization of banana diversity. The present study on indigenous bananas was carried out with a special emphasis on getting a geographical indication (GI) for the products. Geographical Indications (GIs) were introduced into international trade treaties by the European Union (EU) during the Uruguay Round trade negotiations. Geographical indication of agricultural or natural or manufactured goods which identifies its originating country or territory, or a region or locality of that country or territory, where any specific quality, reputation or other characteristic of the goods is essentially attributable to its geographical origin (Moschini *et al.*, 2008). GIs are thus a form of Intellectual Property Rights that are associated with the geography, culture, heritage and traditional practices of people and countries (Teuber, 2011). GI has received special attention recently, mainly due to the interest of the breeder in terms of protection and also because the international market is becoming very competitive (Deselnicu *et al.*, 2013, Török *et al.*, 2020). Therefore, safe identification becomes indispensable for cultivar registration or protection (Rani & Kumar 2013).

Bangladesh has passed the Geographical Indication of Goods (Registration and Protection) Act, 2013 to protect the indigenous crops species, foods, clothes, and cultures (Zahur, 2017). So far Bangladesh has got GI registration of nine goods among which Kalojeera rice, Kataribhog rice, Hilsaha fish, and Khirshapari mango are crop items.

A good number of indigenous banana cultivars could be eligible to get GI certificates. Thus, the collected banana cultivars were characterized by efficient qualitative morphological descriptors to determine the specifications that met the expected quality parameters before formally proposing a GI.

This research could add valuable insights into the horticulturists, policymakers, GI registration authorities and consumers.

Broad Research objectives:

The objectives of this study were to collect, characterize of different cultivated and indigenous banana accession and yield performance evaluation for GI protection, conservation, future varietal development for the growers.

Specific Objectives:

1. To collect cultivated indigenous banana plant genetic resources from all over the country.
2. To study the morphological diversity of the collected indigenous banana cultivars

MATERIALS AND METHOD

Collection of banana cultivars

To accomplish the objectives of the study, seventy indigenous banana cultivars were collected. Before the final selection of a sample, after initial observation of the plant, informal interviews were arranged with the local farmer that included the history of the cultivar, qualitative and

quantitative information about the quality of fruit, yield; and any special features such as sustainability against water, wind etc. The gathered information was recorded in field notes. After negotiating the price with the farmer, the sucker with the corm was collected.

Of the fifty-five transplanted banana cultivars (desert type) under the study (out of seventy collected samples); twenty were collected from the southern districts, ten from the northern districts, ten from the hilly districts in the east and the remaining fifteen samples from the native district of the experiment.

Growing and Nursing

The collected banana accession was planted at Bangladesh Agricultural University Germplasm Center (BAU-GPC) following randomized complete block design with three replications. Each cultivar was given an accession number, like, MS001, or MS002. The terminology 'Accession' has been used to indicate all the 'banana cultivars' that have been collected under this research work and each cultivar was given a definite accession number. Recommended doses of manures and fertilizers were used during planting and growth of plant. Irrigation was applied during dry months. Insects and diseases were controlled by application of proper insecticides and fungicides.

Data Analysis

The collected morphological data were examined, tabulated, and analysed by a statistical programme MSTAT-C following the arranged design of the experiment. The significance of the difference between pairs of means was performed by the Least Significant Differences (LSD) test taking the probability level 1% as the maximum and 5% as the minimum unit of significance.

RESULT

Fruit colour

Thirteen different colours were observed in dessert banana accessions, such as golden yellow, dark golden yellow, dark orange yellow, dark red, dark purple-red, greenish-yellow, reddish-yellow, yellow-green, and dark orange yellow. Out of 55 accessions yellow was the major colour covering 40% of the total accessions. Nearly 16% of accessions showed orange-yellow colour. Both golden yellow and greenish-yellow covered nearly 10% of the accessions under study.

Table 1. Fruit character - Grouping based on the fruit colour of (peel)

Type	Total number	Accession No.
Dark golden yellow	1	MS011
Dark orange yellow	1	MS024
Dark purple red	2	MS020, MS032
Dark red	1	MS001
Golden yellow	6	MS007, MS008, MS009, MS012, MS022, MS042
Greenish yellow	5	MS006, MS026, MS046,

Type	Total number	Accession No.
		MS048, MS054
Light yellow green	1	MS044
Orange yellow	9	MS034, MS039, MS040, MS043, MS045, MS047, MS050, MS052, MS053
Red	1	MS005
Reddish yellow	3	MS002, MS049, MS055
Yellow	22	MS003, MS004, MS010, MS013, MS014, MS015, MS018, MS019, MS021, MS023, MS025, MS027, MS028, MS029, MS030, MS031, MS033, MS035, MS036, MS037, MS038, MS041
Yellow with black spot	1	MS051
Yellow green	2	MS016, MS017

Pulp colour

Ten different types of pulp colour were observed in selected 55 accessions of desert banana cultivars. The dominant colour was cream (50%) followed by light cream and orange cream.

Table 2. Fruit character - Grouping based on pulp colour

	Total number	Accession No.
Cream	27	MS003, MS004, MS007, MS008, MS010, MS012, MS013, MS020, MS022, MS023, MS026, MS029, MS030, MS031, MS035, MS036, MS037, MS038, MS041, MS046, MS047, MS048, MS049, MS050, MS051, MS054, MS055
Dark cream	2	MS043, MS052
Dark orange yellow	1	MS021
Light cream	7	MS006, MS011, MS014, MS015, MS016, MS017, MS044
Light orange yellow	2	MS002, MS019
Light yellow	1	MS018
Orange	1	MS040
Orange cream	8	MS027, MS032, MS033, MS034, MS039, MS042, MS045, MS053
Orange yellow	2	MS001, MS005
Yellowish cream	4	MS009, MS024, MS025, MS028

Presence of seeds

The presence of seed is an important factor for banana quality and price. The consumer usually likes seedless pulp. Out of 55 accessions, 45% were found with seed and the rest 55% were seedless.

Table 3. Fruit character (dessert accession) - Grouping of accessions based on presence of seed

Type	Total number	Accession No.
Seed present	25	MS003, MS004, MS006, MS008, MS011, MS014, MS015, MS016, MS017, MS019, MS022, MS026, MS040, MS044, MS045, MS046, MS047, MS048, MS049, MS050, MS051, MS052, MS053, MS054, MS055
Absent	30	MS001, MS002, MS005, MS007, MS009, MS010, MS012, MS013, MS018, MS020, MS021, MS023, MS024, MS025, MS027, MS028, MS029, MS030, MS031, MS032, MS033, MS034, MS035, MS036, MS037, MS038, MS039, MS041, MS042, MS043

Fruit weight

The fruit (finger) weights of the selected accessions of desert-type bananas were compared. Fruit weights from the first hand to the eighth hand were considered. The number of hands bearing at least one maturing finger was four to eight. The highest finger weight (410 g) was recorded in (MS020) and the lowest weight (14 g) was found in MS027.

Table 4. Fruit characters showing variability on weight of each fruit (finger) (Peel + Pulp)

Accession No.	Weight of each fruit (g)							
	1st hand	2nd hand	3rd hand	4th hand	5th hand	6th hand	7th hand	8th hand
MS001	188.67	182.00	135.33	162.67	0.00	0.00	0.00	0.00
MS002	94.00	61.33	105.33	79.33	74.00	61.33	62.00	0.00
MS003	196.00	167.33	201.33	153.33	168.67	151.33	0.00	0.00
MS004	85.33	70.00	70.67	73.33	79.33	108.67	69.33	60.00
MS005	132.67	145.33	140.00	132.00	133.33	117.33	104.00	86.67
MS006	262.67	238.00	254.00	244.67	196.67	216.00	180.00	138.67
MS007	55.33	73.33	53.33	59.33	48.00	36.67	45.33	41.33
MS008	110.00	93.33	91.33	97.33	78.00	86.67	79.33	74.67
MS009	146.67	136.00	100.67	120.00	135.33	116.67	108.00	107.33
MS010	94.67	76.00	84.00	90.00	88.67	78.67	83.33	74.00
MS011	201.33	173.33	194.00	146.00	201.33	178.67	150.67	0.00
MS012	149.33	152.00	152.00	140.67	124.67	0.00	0.00	0.00
MS013	86.67	88.00	80.00	60.00	65.33	65.33	66.67	30.67
MS014	225.33	214.00	188.00	185.33	145.33	0.00	0.00	0.00
MS015	206.67	206.00	222.67	194.67	195.33	160.00	158.67	0.00
MS016	190.67	173.33	180.67	184.67	188.67	176.00	142.67	0.00
MS017	204.00	200.67	208.67	175.33	208.67	166.00	0.00	0.00
MS018	225.33	228.67	218.00	210.67	175.33	173.33	154.67	156.67
MS019	59.33	58.67	68.00	70.00	0.00	0.00	0.00	0.00
MS020	410.00	383.33	402.00	359.33	380.00	354.00	198.00	0.00
MS021	72.67	74.00	61.33	74.00	66.67	68.67	59.33	52.00
MS022	128.00	138.67	141.33	118.00	120.00	116.00	104.67	0.00
MS023	86.67	100.00	85.33	95.33	101.33	100.67	86.00	79.33
MS024	196.00	176.00	197.33	172.00	171.33	147.33	166.67	148.67
MS025	178.00	185.33	169.33	159.33	124.67	144.67	137.33	108.00
MS026	122.67	118.00	116.00	112.00	122.67	120.67	72.67	96.67
MS027	14.67	14.00	15.33	16.67	15.33	20.00	17.33	15.33
MS028	94.67	99.33	98.00	96.00	84.67	76.00	70.67	71.33
MS029	165.33	149.33	170.00	146.00	156.67	150.67	132.00	0.00
MS030	220.00	274.67	237.33	259.33	251.33	226.00	160.00	0.00
MS031	174.67	171.33	166.67	154.67	169.33	147.33	0.00	0.00
MS032	291.33	276.67	256.00	274.67	0.00	0.00	0.00	0.00
MS033	224.00	159.33	152.00	78.67	0.00	0.00	0.00	0.00
MS034	142.67	142.67	124.00	130.67	118.00	122.00	123.33	111.33
MS035	113.33	108.00	106.67	94.00	91.33	94.67	84.67	77.33
MS036	112.67	113.33	102.67	106.00	110.67	76.00	86.67	88.67
MS037	167.33	147.33	158.67	159.33	155.33	126.67	115.33	116.00
MS038	167.33	147.33	158.67	159.33	155.33	126.67	115.33	116.00
MS039	80.67	85.33	88.00	76.67	67.33	76.67	60.00	0.00
MS040	54.67	45.33	44.67	42.67	24.00	19.33	0.00	0.00
MS041	91.33	96.67	92.00	84.67	80.67	76.00	65.33	58.00
MS042	132.67	145.33	140.00	132.00	133.33	117.33	104.00	86.67
MS043	130.00	118.67	122.00	95.33	115.33	120.00	108.67	88.00
MS044	290.00	58.67	195.33	249.33	210.67	171.33	177.33	199.33
MS045	174.67	172.00	168.67	176.00	144.67	143.33	127.33	0.00
MS046	238.67	48.67	198.00	252.00	234.00	0.00	0.00	0.00
MS047	103.33	110.67	108.00	92.67	87.33	87.33	70.67	71.33
MS048	324.00	314.67	367.33	336.00	421.33	410.67	372.00	375.33
MS049	264.00	259.33	264.00	303.33	340.00	316.00	322.67	286.67

Accession No.	Weight of each fruit (g)							
	1st hand	2nd hand	3rd hand	4th hand	5th hand	6th hand	7th hand	8th hand
MS050	220.00	224.67	222.00	221.33	217.33	198.00	262.67	204.67
MS051	338.67	185.33	182.67	158.67	196.00	187.33	197.33	198.00
MS052	90.67	75.33	94.67	82.67	84.00	92.00	80.67	0.00
MS053	294.00	337.33	368.00	372.67	358.00	385.33	290.00	294.67
MS054	224.00	205.33	209.33	214.00	202.00	180.67	211.33	172.67
MS055	316.00	264.00	254.00	50.67	55.33	170.67	164.00	-
Mean weight	170.25	153.87	153.73	150.64	-	-	-	-
LSD _{0.05}	27.86	23.67	21.98	29.87	-	-	-	-
LSD _{0.01}	36.96	31.40	29.16	39.62	-	-	-	-
Level of sign.	**	**	**	**	Not Defined (ND)	ND	ND	ND

Finger weight gradually decreased with the progressing hand number. However, the average weights of fingers in the second, third and fourth hands were closer. In the first hand, more than 30% fingers were found at least 200 g or above in weight. In the eighth hand, MS044, MS048, MS049, MS050, and MS 053 accession yielded healthy fingers (more than 200 g).

Pulp weight

The pulp weight of the selected 55 accessions was assessed and compared. The highest pulp weight (327g) was recorded in MS020 (firsthand) and the lowest pulp weight was recorded in MS027 (third hand). The highest average pulp weight was found in fingers from the first hand and it gradually decreased with the progressing hands.

Table 5. Fruit characters showing variability in pulp weight

Accession No.	Weight of pulp (g)							
	1st hand	2nd hand	3 rd hand	4th hand	5th hand	6th hand	7th hand	8th hand
MS001	148.34	140.33	100.33	123.00	0	0	0	0
MS002	73.67	38.33	84.33	58.00	53.67	43.66	45.00	0
MS003	172.33	143.33	176.66	128.00	144.34	126.33	0	0
MS004	70.00	54.33	54.34	57.33	64.33	96.00	56.66	44.00
MS005	96.00	104.00	102.00	97.00	95.66	83.33	73.33	60.00
MS006	195.67	175.33	204.33	197.34	141.34	169.33	130.00	102.00
MS007	46.00	64.33	46.00	52.33	40.33	29.00	37.33	33.00
MS008	94.67	78.33	76.00	80.33	64.33	72.34	66.00	58.67
MS009	121.34	114.00	80.34	98.00	113.33	95.00	88.33	83.33
MS010	78.00	61.00	69.33	75.00	75.00	64.67	69.66	59.33
MS011	174.33	149.00	164.33	125.00	181.00	154.00	126.00	-
MS012	127.66	127.33	130.33	120.00	104.00	-	-	-
MS013	75.67	69.00	63.67	46.33	54.33	54.00	55.34	19.34
MS014	160.66	156.33	134.33	136.33	102.66	-	-	-
MS015	160.00	164.33	182.00	157.00	159.33	125.00	130.34	-
MS016	142.00	129.33	136.00	147.00	143.00	139.67	107.67	-
MS017	156.00	153.34	170.34	133.33	170.00	129.00	-	-
MS018	189.00	193.00	183.67	175.67	141.33	138.66	121.00	125.67
MS019	45.66	45.00	51.00	54.33	-	-	-	-
MS020	327.00	304.33	321.67	287.00	310.00	290.00	154.00	-
MS021	62.34	61.67	50.33	62.33	54.00	55.67	49.66	42.33
MS022	111.00	121.34	123.33	102.33	104.00	99.33	89.34	-
MS023	72.67	85.33	72.66	82.00	86.00	85.34	74.33	68.00
MS024	166.67	149.00	168.33	144.33	146.33	122.00	140.00	122.67
MS025	136.00	139.33	128.00	120.66	87.67	104.34	95.33	70.33
MS026	84.34	84.33	81.33	90.67	98.00	97.00	52.34	74.00
MS027	12.34	10.67	12.66	13.67	11.33	18.00	14.66	13.33
MS028	72.67	74.00	76.67	77.00	64.34	54.67	50.00	53.66
MS029	138.33	126.66	143.00	124.67	130.34	127.34	109.67	-
MS030	179.00	233.00	198.00	216.33	221.00	199.67	137.67	-
MS031	150.00	148.00	139.67	132.67	145.33	124.00	-	-
MS032	243.66	224.67	209.00	225.78	-	-	-	-
MS033	132.33	63.33	73.67	31.34	-	-	-	-
MS034	110.34	113.00	97.67	102.34	90.00	94.33	95.33	86.66
MS035	99.00	91.00	89.00	78.00	77.00	78.00	69.00	62.00
MS036	95.67	97.00	87.34	89.33	94.67	63.67	70.67	73.67
MS037	145.00	125.66	136.34	138.66	134.66	108.67	99.00	99.00
MS038	145.00	125.66	136.34	138.66	134.66	108.67	99.00	99.00
MS039	60.34	68.33	71.33	56.34	49.00	58.67	42.67	-
MS040	44.34	35.66	35.34	36.00	17.00	14.33	-	-
MS041	73.00	75.34	74.00	68.00	63.00	60.67	51.66	45.00
MS042	96.00	104.00	102.00	97.00	95.66	83.33	73.33	60.00
MS043	106.00	90.67	97.67	72.66	91.33	94.67	86.00	67.00
MS044	214.00	27.34	137.00	179.66	151.00	118.66	124.00	144.33
MS045	135.00	133.33	134.00	139.67	108.67	111.66	98.33	-
MS046	191.00	18.34	149.67	199.33	186.00	-	-	-
MS047	85.66	92.34	88.00	72.00	68.33	68.00	52.00	53.33
MS048	229.67	227.00	264.66	235.33	320.00	316.34	276.00	279.66

Accession No.	Weight of pulp (g)							
	1st hand	2nd hand	3 rd hand	4th hand	5th hand	6th hand	7th hand	8th hand
MS049	195.33	188.33	196.67	233.66	260.33	241.33	248.00	221.34
MS050	137.00	141.34	145.00	144.66	144.66	129.33	188.00	134.00
MS051	262.34	128.66	127.67	108.00	136.00	130.00	140.66	152.33
MS052	71.34	57.00	77.67	64.00	64.00	74.33	63.67	-
MS053	226.00	264.00	300.67	299.00	288.67	311.33	234.33	236.34
MS054	190.67	167.66	166.66	170.67	163.33	145.67	176.00	142.67
MS055	238.67	184.00	177.67	22.67	3.66	104.00	98.00	-
LSD _{0.05}	13.93	11.83	10.99	14.92	-	-	-	-
LSD _{0.01}	18.48	15.70	14.58	19.79	-	-	-	-
Level of sign.	**	**	**	**	Not Defined	ND	ND	ND

Fruit length

The fruit length of the selected accession was assessed and compared. To measure fruit length, pedicel, edible portion, and tip were taken into consideration. The highest fruit

length (23.89 cm) was found in MS033 (firsthand) and the lowest fruit length (5.79 cm) was recorded in MS027. The average fruit length of fingers from the first four hands was closer (13.3-14.0 cm).

Table 6. Fruit characters showing variability on total fruit length (cm) (Pedicel + Edible portion + Tip)

Accession No.	Total fruit length (cm)							
	1st hand	2nd hand	3rd hand	4th hand	5th hand	6th hand	7th hand	8th hand
MS001	11.88	12.84	11.23	11.64	-	-	-	-
MS002	11.36	12.36	11.63	11.23	10.85	10.59	10.71	-
MS003	12.88	13.13	12.85	11.89	11.72	10.86	-	-
MS004	12.35	13.01	12.14	13.08	12.02	11.88	11.84	11.33
MS005	20.50	20.71	20.74	19.14	18.61	18.41	16.94	15.86
MS006	18.54	18.59	17.77	17.83	16.56	15.55	16.16	14.71
MS007	7.52	8.11	9.99	7.83	7.63	7.55	9.57	6.95
MS008	10.51	10.30	11.00	10.70	10.38	10.69	10.33	10.13
MS009	12.47	11.70	11.47	11.37	11.61	11.14	10.66	10.63
MS010	13.10	12.65	12.31	12.78	11.85	11.70	11.66	11.63
MS011	12.89	12.57	13.16	12.30	12.25	11.35	11.58	-
MS012	11.26	12.41	11.94	10.37	10.49	-	-	-
MS013	11.64	12.63	11.83	11.25	10.83	10.45	10.92	9.12
MS014	14.25	14.48	14.22	13.78	12.90	-	-	-
MS015	13.87	14.04	14.16	13.14	13.14	12.33	11.87	-
MS016	14.22	14.02	13.99	13.39	14.47	13.26	12.67	-
MS017	14.39	14.83	13.86	14.35	13.13	13.14	-	-
MS018	16.53	16.95	16.24	14.97	15.00	16.12	16.26	16.22
MS019	9.72	9.44	9.93	9.90	-	-	-	-
MS020	20.11	19.56	19.05	18.63	20.28	18.94	16.53	-
MS021	10.92	10.89	11.45	10.50	10.11	9.99	9.13	8.50
MS022	12.48	11.23	12.32	10.96	11.51	11.99	12.27	-
MS023	11.80	12.39	11.45	12.51	11.95	12.58	11.94	9.50
MS024	15.55	15.61	15.93	15.11	16.02	16.69	15.65	15.65
MS025	15.29	16.49	16.02	14.33	14.35	13.34	13.27	12.34
MS026	14.22	14.10	13.51	12.20	14.25	11.79	10.50	11.30
MS027	5.79	5.98	6.10	5.99	6.28	5.99	6.23	5.99
MS028	13.25	14.30	13.46	13.28	12.71	12.60	12.43	10.25
MS029	13.37	12.81	13.47	11.38	12.32	12.68	11.92	-
MS030	13.27	14.60	13.57	12.46	12.91	11.92	11.40	-
MS031	13.16	13.13	12.92	12.51	12.68	11.93	-	-
MS032	15.08	14.15	12.32	13.78	-	-	-	-
MS033	23.89	23.58	23.52	18.61	-	-	-	-
MS034	14.48	14.23	13.63	12.83	13.57	13.37	13.90	11.71
MS035	12.53	12.58	13.05	12.07	11.67	11.63	10.45	10.77
MS036	10.71	10.71	9.61	11.03	10.53	8.54	8.48	10.80
MS037	13.23	12.26	13.07	12.63	12.39	11.65	10.78	10.87
MS038	12.67	12.26	13.07	12.63	12.39	11.65	10.78	10.87
MS039	11.70	11.82	10.85	11.01	10.81	10.63	8.07	-
MS040	8.97	9.92	9.58	7.78	7.91	6.48	-	-
MS041	12.00	12.80	11.87	11.07	11.56	11.40	10.93	10.16
MS042	20.50	20.71	20.74	19.14	18.61	18.41	16.94	15.86
MS043	14.71	13.95	13.94	12.66	12.88	12.97	11.97	11.24
MS044	18.34	13.20	18.04	17.41	17.75	14.79	16.25	15.58
MS045	13.87	14.37	14.12	14.07	13.67	11.97	11.68	-
MS046	14.41	12.65	15.75	17.24	16.37	-	-	-
MS047	11.82	11.16	11.44	10.87	10.83	10.79	10.48	9.79
MS048	18.30	18.72	18.81	19.09	17.75	18.44	17.68	17.90
MS049	15.54	17.22	16.89	17.43	17.71	17.80	16.92	16.44
MS050	16.08	15.04	15.20	14.71	13.63	14.61	15.73	13.68
MS051	18.18	16.27	16.02	14.83	15.97	15.30	13.63	15.96
MS052	12.77	12.23	12.02	12.74	12.08	12.17	11.77	-
MS053	18.17	18.39	16.14	18.79	16.73	17.37	16.31	14.90
MS054	16.49	16.90	16.97	17.08	16.41	15.57	16.52	15.64
MS055	19.52	18.75	17.29	11.44	13.90	16.45	16.25	-
LSD _{0.05}	1.04	0.94	1.16	0.96	-	-	-	-
LSD _{0.01}	1.38	1.24	1.54	1.28	-	-	-	-
Level of sign.	**	**	**	**	Not Defined (ND)	ND	ND	ND

Fruit diameter

The fruit diameter of the selected accession was assessed and compared. The highest average fruit diameter (3.8 cm) was

found firsthand. The average fruit diameter of fingers from the second to fourth hands was almost closer. The lowest diameter of the finger was 1.8 cm (accession M044)

Table 1. Fruit characters showing variability in the diameter of fruit

Accession No.	Diameter of fruit (cm)							
	1st hand	2nd hand	3rd hand	4th hand	5th hand	6th hand	7th hand	8th hand
MS001	3.82	3.85	3.85	3.80	-	-	-	-
MS002	3.17	3.01	3.22	2.97	3.03	2.59	2.51	-
MS003	3.66	3.34	3.65	3.52	3.64	3.64	-	-
MS004	2.55	2.84	2.91	2.79	2.70	2.90	2.62	2.83
MS005	4.68	4.85	4.79	4.73	4.91	4.74	4.62	4.55
MS006	4.50	4.46	4.44	4.35	4.54	4.40	4.37	3.39
MS007	2.54	3.08	2.63	2.37	2.45	2.39	2.66	2.56
MS008	3.56	3.21	3.31	3.41	3.13	3.15	3.01	4.93
MS009	3.83	3.71	3.31	3.50	3.72	3.80	3.42	3.65
MS010	2.85	2.67	2.85	2.89	2.87	2.76	2.77	2.74
MS011	4.01	3.99	4.08	3.80	4.00	3.79	3.68	-
MS012	3.79	3.87	3.61	3.58	3.69	-	-	-
MS013	3.26	3.32	3.17	2.87	2.82	2.55	2.49	2.16
MS014	4.40	4.14	4.10	4.14	4.03	-	-	-
MS015	4.16	3.97	4.11	4.13	4.03	3.81	3.71	-
MS016	3.84	3.82	3.86	3.75	4.04	3.78	3.64	-
MS017	4.02	3.98	4.18	3.76	3.71	3.99	-	-
MS018	4.08	3.90	4.02	3.63	3.49	4.33	4.14	3.63
MS019	2.62	2.53	2.58	3.21	-	-	-	-
MS020	4.88	4.79	5.19	4.93	5.28	5.54	4.43	-
MS021	2.73	2.83	2.69	2.87	2.65	2.83	2.61	2.68
MS022	3.41	3.54	3.53	3.08	3.37	3.32	3.27	-
MS023	2.78	2.87	3.02	2.82	2.97	2.98	3.08	2.90
MS024	3.79	3.66	3.81	3.73	4.09	3.94	3.99	4.00
MS025	3.46	3.78	3.80	3.69	3.53	3.66	3.68	3.37
MS026	3.62	3.90	3.96	3.68	3.74	3.77	3.38	3.23
MS027	2.40	1.93	1.88	2.08	2.05	2.05	2.06	1.88
MS028	2.90	2.75	2.54	2.55	2.69	2.75	2.39	2.37
MS029	3.50	3.39	3.51	3.48	3.78	3.58	3.51	-
MS030	3.53	3.88	3.29	3.40	3.47	3.43	3.31	-
MS031	3.70	3.73	3.68	3.68	3.80	3.65	-	-
MS032	4.72	4.67	4.80	4.73	-	-	-	-
MS033	4.04	3.73	3.45	2.77	-	-	-	-
MS034	3.43	3.31	3.23	3.42	3.35	3.33	3.25	3.18
MS035	3.27	3.25	3.34	3.15	3.17	3.21	3.06	3.06
MS036	3.29	3.44	3.10	3.03	3.28	2.66	2.91	3.15
MS037	3.59	3.60	3.72	3.62	3.54	3.60	3.05	3.13
MS038	3.59	3.60	3.72	3.62	3.54	3.60	3.05	3.13
MS039	3.19	3.21	3.23	3.28	3.08	3.23	3.06	-
MS040	2.43	2.32	2.32	2.42	1.91	1.76	-	-
MS041	3.34	3.43	3.48	3.61	3.50	3.32	3.37	3.20
MS042	4.68	4.85	4.79	4.73	4.91	4.74	4.62	4.55
MS043	4.41	4.29	3.85	3.02	3.87	3.46	3.03	3.00
MS044	4.62	2.81	1.80	4.69	4.78	4.36	3.87	4.20
MS045	4.44	4.27	4.30	4.39	4.09	4.32	4.19	-
MS046	4.56	2.83	4.39	4.63	4.63	-	-	-
MS047	3.30	3.26	3.44	3.40	3.24	3.21	3.04	3.09
MS048	5.07	4.64	4.43	4.96	4.56	4.92	4.16	5.02
MS049	4.98	5.15	5.25	5.36	5.64	5.32	5.53	5.31
MS050	4.22	4.28	3.86	3.81	4.13	4.24	4.06	4.98
MS051	5.63	4.69	4.64	4.53	4.86	4.82	4.81	4.68
MS052	2.88	2.72	3.03	2.60	2.83	2.84	2.44	-
MS053	5.71	5.62	5.46	5.62	5.80	5.42	5.35	5.69
MS054	4.25	4.70	4.63	4.57	4.57	4.34	4.69	3.76
MS055	4.97	4.82	4.03	2.75	3.37	4.78	4.42	-
LSD _{0.05}	0.35	0.31	0.36	0.34	-	-	-	-
LSD _{0.01}	0.46	0.41	0.47	0.45	-	-	-	-
Level of sign.	**	**	**	**	Not Defined	ND	ND	ND

Days to inflorescence initiation and Maturity

The days to inflorescence initiation and maturity vary from accession to accession. The average days for inflorescence initiation was 529. Accession no MS041 took the highest

time (892 days) for inflorescence initiation. The lowest day for inflorescence initiation was recorded in MS027 accession.

Table 8. Fruit descriptors showing variability on days to inflorescence initiation, Days to maturity and yield per plant.

Accession No.	Days to Inflorescence Initiation	Days to Maturity	Yield (kg)/plant
MS001	854.00	109.67	6.30
MS002	601.67	110.00	7.67
MS003	747.67	99.33	9.68
MS004	528.33	149.00	8.95
MS005	341.00	112.67	11.21
MS006	458.33	169.67	21.61
MS007	840.00	202.33	5.04
MS008	317.67	115.00	8.78
MS009	373.00	170.67	17.24
MS010	304.33	229.00	8.48
MS011	541.33	126.33	13.49
MS012	774.33	113.33	5.23
MS013	383.00	283.00	7.84
MS014	759.33	134.67	12.93
MS015	561.00	110.00	14.68
MS016	583.00	125.67	13.40
MS017	436.00	159.67	13.57
MS018	387.33	147.00	18.52
MS019	535.67	152.67	3.07
MS020	382.00	128.00	21.66
MS021	572.67	121.00	5.55
MS022	797.00	99.67	8.00
MS023	382.33	131.67	12.88
MS024	549.33	141.33	19.60
MS025	583.00	148.33	16.72
MS026	438.33	173.33	17.67
MS027	260.00	143.33	2.50
MS028	429.00	108.00	12.33
MS029	492.00	152.00	10.41
MS030	350.00	116.33	14.63
MS031	375.33	92.33	8.06
MS032	404.33	131.67	7.24
MS033	637.33	162.33	7.99
MS034	374.33	127.00	19.42
MS035	414.67	124.33	11.78
MS036	375.67	111.67	11.13
MS037	390.67	110.00	10.60
MS038	305.00	116.67	10.64
MS039	585.67	139.67	6.60
MS040	671.33	165.67	2.08
MS041	892.67	255.33	13.82
MS042	333.00	109.00	11.21
MS043	408.33	128.33	9.46
MS044	606.00	170.33	32.68
MS045	614.00	132.33	8.62
MS046	622.67	126.67	8.29
MS047	507.00	221.00	10.45
MS048	708.33	175.00	32.27
MS049	702.00	151.33	24.56
MS050	759.67	179.00	29.34
MS051	576.67	152.33	19.42
MS052	604.00	278.00	8.46
MS053	609.67	158.00	20.45
MS054	660.67	221.67	21.66
MS055	417.67	243.67	14.14
LSD _{0.05}	10.58	20.52	1.55
LSD _{0.01}	14.04	27.22	2.06
Level of sign.	**	**	**

Yield Performance

The yield performance of the selected accession was compared and evaluated (Table 8). The average yield was recorded as 13.77 kg per plant. The highest yield (32.68 kg/plant) was recorded in accession MS044 and the lowest yield (2.08 kg/plant) was recorded in accession MS040.

DISCUSSION

As a popular and widely consumed fruit, the morphological character is important to consumers. Consumers' preferences vary depending on colour, size, weight and taste. The presence of seeds is an important consideration for commercial varieties. Commercial producers consider crop duration (days to inflorescence initiation and maturity), yield and shape.

Yellowish fruits colour with different colour combinations (e.g. golden yellow, greenish yellow, reddish yellow) are the common colour of bananas throughout the world. However, a few rare colour (red, yellow, red, greenish red) cultivars are of interest to the consumers and breeders.

Pulp colour varies slightly. However, consumers' preferences for colour can not be ignored. Out of 55 accessions, cream colour (e.g. cream, dark cream, yellow cream, light cream) is the dominant pulp colour. Pulp colour changes with ripening due to biochemical changes ([Chillet *et al.*, 2014](#)). In case of over-ripening, the pulp colour becomes darker ([Amini Khoozani *et al.*, 2019](#)). The colour of the peel and pulp might be an indicator of the eating quality, texture and storability of banana ([Salvador *et al.*, 2007](#)).

Banana is usually seedless and consumers prefers seedless varieties. However, many varieties develop seeds in the pulp, reducing its market value. Out of 55 accessions, nearly half of the varieties are seeded. Most of the commercial varieties are seedless ([Tien *et al.*, 2022](#)). In Bangladesh, seeded varieties are considered to have medicinal value and those varieties are popular to consumers, who believe in medicinal attributes ([Kumar *et al.*, 2012](#)).

Fruit size and weight is an important consideration for commercial banana cultivars. Fruit weight depends on largely on variety, cultivation procedures, and maturity. This research found too big (410 g) and too small (14 g) fingers. Consumers prefer moderate size fingers ranging from 100 g to 200 g. Partially matured fingers are smaller in size.

Banana is a long duration crop, therefore, days to inflorescence initiation and maturity is important considerations. Productivity levels of banana production differ from country to country and from variety to variety. In general, within commercial banana production of the Cavendish variety, the average yield per hectare ranges between 40 and 50 tonnes. Overall, the banana industry has achieved rapid productivity improvements, with the average yield increasing from around 14 tonnes per hectare in 1993 to 21 tonnes per hectare in 2020 ([FAO, 2022](#)). The average yield of the indigenous banana cultivars was found 30.0 tons/ha (considering 12 kg per plant and the total population per hectare was 2500), which is higher than the global average. More than half of the accession gave a higher yield than the global average. Thus, indigenous banana cultivars have commercial importance in Bangladesh.

CONCLUSION

The morphological characterization of 55 indigenous banana cultivars summarized valuable information and insights, which could be used to registration for Geographic Indication. The selected cultivars showed significant variation in color (peel and pulp), weight (fruit and pulp), maturity time and yield performance. This morphological variation could be a source of research insights for genetic research. This research is likely to stimulate research and policy initiative to conserve indigenous fruits cultivars. Further research initiative for a comprehensive collection of indigenous banana cultivars (both desert and plantain type) from all agricultural regions is suggested. More detailed study of these cultivars might help in screening sustainable and high-yielding bananas in changing environments, market dynamics and consumer preferences.

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Author's contribution

Setara-E-Bilkis contributed to the collection of banana accession, conservation, data collection, data analysis & manuscript preparation.

Md. Mokter Hossian contributed to collection of banana accession, conservation, data collection, data analysis & manuscript preparation.

Md Abdur Rahim supervised and coordinated the collection of banana accession, data collection, data analysis and manuscript preparation.

Md Habibur Rahman contributed to the revision of the manuscript.

Md Roushon Jamal contributed to data analysis, manuscript preparation and submission to the journal.

Conflict of interest

The authors confirm that there are no known conflicts of interest associated with this publication.

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