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BJRI Mesta 4: A Newly Released Improved Vegetable Mesta Variety of *Hibiscus Sabdariffa* L.

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ABSTRACT

Vegetable mesta, or roselle, is a common species in many countries for confectioneries and a good source of nutrients and antioxidants. BJRI Mesta 4 is a nutrient-rich, climate-smart, and widely adaptable vegetable Mesta cultivar developed by the Bangladesh Jute Research Institute (BJRI) and released by the National Seed Board (NSB) in 2022. To explore the superiority of the new variety, a study was conducted on yield and yield components using multivariate analysis over two planting seasons compared with the well-known variety BJRI Mesta 2. Significant differences ($p \le 0.01$ or 0.05) were recorded among the qualitative and quantitative traits. In multi-location Trials during 2018 and 2019, the average yield of leaf, fruit, and calyx of BJRI Mesta 4 was found to be 7.25%, 11.51%, and 10.49% higher in BJRI regional stations, respectively, compared to the check variety. Plant height, branches per plant, fruit yield, and leaf yield were considered when selecting vegetable mesta types with appropriate yields. However, based on yield capacity, adaptability, and nutraceutical properties, the newly released cultivar BJRI Mesta 4 can be recommended and promoted to the herbal food product industry in addition to being a substitute for leafy vegetables. With these views in mind, the study conducted now may help create trustworthy selection criteria for future programs to improve vegetable mesta breeding.

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Introduction

Vegetable mesta or Roselle (*Hibiscus sabdariffa* L.) is commonly known as "Mesta" or "chukur" in Bangladesh and the Indian subcontinent. It is a kind of Hibiscus from the "Malvaceae" family, most likely from West Africa (Shoosh, 1993), and it is widely available in tropical regions, especially in African nations (Abu-Tarboush et al., 1997). Mesta has two unique botanical classes: the fiber-producing var. altissima and the edible var. (Sobhan, 1993). The edible variety is a short bushy plant (1 - 2 m) bearing profuse smooth fruits, known as roselle or rosella (Dempsey, 1975). Its fleshy calyx and epicalyx are used for jelly making, and the dried form is processed into other confections like cordial drinks, jams, sauces, liqueurs, wines, and food preserves (Mostofa et al., 2021).

Mesta is known for its adaptability to poor soils and exhibits a fair tolerance to drought. Traditionally, it is grown in Bangladesh on relatively less fertile marginal uplands where jute or other major field crops cannot be grown profitably in the Kharif (Monsoon) season (Mostofa et al., 2021). An annual plant's production cycle takes about six months to complete. More than 300 roselle species are found worldwide (Balarabe, 2019). Mesta is a time-bound plant, so the flowering time is fixed from November to December (Mostofa et al., 2021). The tropics provide three separate color groups: green, crimson, and dark red (Purseglove 1977). The leaves of the green forms are eaten as vegetables, while the calyx of the red and dark red varieties is used to extract juice for a fresh drink (Islam et al., 2016). Its attractive color, unique sour taste, and multi-purpose uses made it famous worldwide (Tareq et al., 2021).

Several recipes use the seeds, leaves, fruits, and roots of vegetables as well as other components of the plant. Tender leaves of Mesta are used for preparing curry (or) chutney in several parts of the country. The fruit (capsule), which is surrounded by a fleshy calyx (sepal), is used to make wine, juice, jam, jelly, syrup, gelatin, pudding, cakes, ice cream, pickles, tea, drink, and other confections (Mohamed et al., 2012), is the component of the plant that has the most outstanding commercial significance. The green leaves and fruit pericarp are used like a spicy version of spinach. Leaves can also be used as tea/beverage. According to scientific evidence, vegetable mesta extract has a high level of antioxidant activity, is anti-proliferative, anti-carcinogenic, anti-hypersensitive, anti-hyper lipidomics, hepato-protective, diuretic, and many other properties (Islam et al., 2016).

BJRI Mesta 4 (VM-2) is a high-producing, prickle-free, and very adaptable vegetable mesta cultivar that the Bangladesh Jute Research Institute recently developed. It was previously selected through an exclusive screening from collected Mesta germplasms of BJRI Gene Bank and trialed against a popular cultivar to assess its agricultural suitability and adaptability to sustainable cultivation conditions. Vegetable Mesta or Roselle is gaining popularity for its vegetable properties only, whereas information on its nutritional and medicinal values is barely recognized. Given this information, an effort was made in 2020 to compare the calyx and leaves of the recently introduced variety BJRI Mesta 4 to the widely used variety BJRI Mesta 2.

The new vegetable Mesta variety with higher yield potentials, adaptability, and a considerable number of antioxidants may improve its consumers' acceptance, which would eventually strengthen the nation’s economy. Utilizing marginal and fallow land to produce BJRI Mesta 4 increases women’s involvement in agriculture in Bangladesh by selling fresh vegetables and confectionaries annually. Similarly, only thorough information and research should be used to identify and suggest a plant for commercial cultivation (Al-Mamun et al., 2022). Only by assessing the crop varieties that are now available can one again gain this knowledge. To determine the yield and yield components of BJRI Mesta 4 compared to the well-known variety BJRI Mesta 2.

Methods & Materials

Mesta strains (branching type) collected from different parts of the country and preserved in the Gene Bank of BJRI were thoroughly screened and tested against the check variety BJRI Mesta 2 under preliminary yield trial, advanced yield trial, and zonal yield trial for assessment of yield performance and other agronomic traits. Based on the results, one advanced line L-911 (ME-4) was selected as the best and upgraded for two years (2018 and 2019) under different topography at Manikganj, Kishanganj, Rangpur, Faridpur, Jessore and Dinajpur. The trials were conducted using an RCB design, with three replications in each plot's 60 m^2 effective area. The advanced line ME-4 and the check variety BJRI Mesta 2 were each given an equal piece of a 10-decimal plot in six BJRI stations.

The seeds of advanced line ME-4 and check variety BJRI Mesta 2 were sown from mid-August to the end of August during the tested years. Intercultural operations such as thinning, weeding, agronomic techniques, and supplemental irrigations were completed simultaneously for entire plots, as Chowdhury and Hassan (2013) recommended. It was raised using only the recommended cultural methods. The crop was harvested from mid-January to the end of January, and necessary records were kept. Leaves data were recorded at 60, 90, and 120 days of crop age. Fruit-relevant data were collected from fifteen randomly selected plants. Data were recorded on plant population, plant height, number of leaves/plant, the weight of leaves/plant, number of branches/plant, number of fruits/plant, weight per fruit, and weight of calyces/fruit.

Data Collection

Eleven quantitative and four qualitative features in total were observed. Fifteen randomly chosen plants were used for each genotype in each replication to collect data for each characteristic. The qualitative factors, including stem color and leaf shape, were observed visually at the seedling and growth stages in the field. Visual observations of flower color, fruit shape, and calyx color were made at the reproductive and mature stages. Quantitative data collected include plant population, plant height, leaves per plant, leaf weight per plant, branches per plant, fruits per plant, single fruit weight, single calyx weight, leaf yield, and fruit yield (Table 1). Among the quantitative characters studied, plant population, leaves/plant, and fruits/plant were verified in the field, and the residual characters were measured at the reproductive and mature stages.

Table 1: Quantitative characters studied from vegetable mesta genotypes

Traits	Unit	Description
Plant population	Lha^{-1}	The number of plants, which were five decimals or 200 square meters, was counted at harvest time.
Plant height	m	At harvest time, the height in meters from the soil's surface to the tips of 15 randomly chosen plants was measured.

Leaves/plant	-	The total numbers of leaves were counted at 60, 90, and 120 days of crop age. The average number of leaves per plant was recorded.
Leaves wt./plant	-	The weight of leaves from the randomly selected 15 plants of each replication was taken on electric balance, and per plant basis weight was calculated.
Branches/plant	-	The number of branches on 15 randomly chosen plants was counted to determine the average branch number per plant.
Fruits/plant	-	The total number of fruits of 15 plants from each replication was counted, and an average number of fruits per plant was recorded.
Single Fruit wt.	gm	The average weight of randomly selected fruit from the 15 selected plants of each replication was weighted on electric balance and the reading.
Single Calyx wt.	gm	The calyx's average weight from each replication's randomly selected fruit was weighted based on electric balance and reading.
Leaf yield	tha^{-1}	The leaf yield data were calculated as follows: Weight of leaves/plant × Plant population/ha
Fruit yield	tha^{-1}	The fruit yield data were calculated as follows: Weight of fruits/plant × No. of fruits/plant × Plant population/ha
Calyx yield	tha^{-1}	The calyx yield data were calculated as follows: Weight of calyces/fruit × No. of fruits/plant × Plant population/ha

Data Analysis

Using SAS 9.4 (SAS Institute, Inc., Cary, N.C., USA), all morphological and yield data were treated for an analysis of variance. Least Significant Difference (LSD), a statistical method, was used to calculate the means comparison. The PROC VARCOMP with limited maximum likelihood (REML) approach in SAS was used to estimate the variance components such as genotypic ($\sigma^2 g$), phenotypic ($\sigma^2 p$), and error ($\sigma^2 e$) from the relevant mean squares for all examined traits. Following Oladosu et al. (2014) methodology, the genetic advance, broad-sense heritability, genotypic coefficient of variation (GCV), and phenotypic coefficient of variation (PCV) were all evaluated.

Findings

Qualitative Variation

The new variety BJRI Mesta 4 is bushy and shorter than the check variety BJRI Mesta 2, with more branches and biomass. The new array is the comparatively dwarf and branching type and is almost resistant to diseases and pests. It possesses a larger fruit size with fleshy calyces. BJRI Mesta 4 is morphologically different from the check one in terms of its stem and fruit color (Figure 1). It has a green stem with purple nodes, and its fruit calyx is green at the early stage but slightly pinkish pigmented at maturity, whereas the check variety (BJRI Mesta 2) has a purple color stem and dark red fruit calyx (Figure 2). Both cultivars produce semi-lobed leaves, smooth stems, and cream-colored flowers.

Characteristics	BJRI Mesta 4 (ME-4)	BJRI Mesta 2 (VM-1)
Plant type and leaf shape	 Dwarf and bushy plants with a higher number of semi-lobed leaves. Leaf and calyx taste sour.	 Dwarf and bushy plants with a higher number of semi-lobed leaves. Leaf and calyx taste sour.
Stem color	 It has a green and smooth stem with purple nodes	 BJRI Mesta 2 has a smooth and purple stem
Flower color	 Flower cream with red center	 Cream-colored flowers

Fruit and fruit calyx	  Fruit capsule (pointed) and reddish green in color. Its fruit calyx is green at the early stage but slightly pinkish-pigmented at maturity.	  Fruit capsule (pointed) and red. Dark red fruit calyx.

Figure 1. Several qualitative traits of BJRI vegetable mesta genotypes

Figure 2. Field view, fruits and calyces of the new variety BJRI Mesta 4 (green) and BJRI Mesta 2 (red)

Morpho-Physiological and Yield Characters

The combined analysis of variance for the six locations showed significant differences ($p \leq 0.01$ or 0.05) for all the evaluated traits except for leaves weight per plant; non-significant differences were observed (Table 2). The range of 11.97 to 48.70 in the CV% for yield and yield-related components indicates that the traits under study are highly variable.

Table 2: Vegetable mesta genotypes for 11 traits were analyzed for variance over two crop seasons

Source of variation	Replication	Locations	Genotypes	Gen*Location	Error	Mean±Std error	CV (%)
Degrees of freedom	2	5	1	5	22		
Plant population (Lha^{-1})	0.47*	0.54**	0.00	0.02	0.12	2.02±0.07	21.11
Plant height (m)	0.25	0.95*	0.17	0.01	0.31	1.94±0.10	30.50
Leaves/plant	34.61	523.08*	32.51	7.98	165.70	27.77±2.25	48.70
Leaves wt./plant	393.42	468.96	4.98	19.86	237.08	53.59±2.59	29.00
Branches/plant	48.89**	25.52**	3.74	1.17	4.39	6.82±0.51	45.15
Fruits/plant	193.72	260.63*	70.28	1.52	92.10	26.46±1.74	39.35
Single Fruit wt. (gm)	0.05	2.54**	0.21	0.15	0.46	6.90±0.14	11.97
Single Calyx wt. (gm)	0.04	0.63**	0.20	0.05	0.15	3.43±0.07	12.96
Leaf yield (tha^{-1})	6.20	31.31**	0.59	0.57	6.08	10.59±0.49	27.93
Fruit yield (tha^{-1})	139.05	751.26*	205.35	8.04	188.71	36.85±2.59	42.12
Calyx yield (tha^{-1})	28.59	176.67*	71.60	2.51	48.20	18.35±1.29	42.07

Data on yield and yield contributing traits of the new variety ME-4 and check variety VM-1 at six BJRI stations, namely Manikganj, Kishoreganj, Rangpur, Faridpur, Jessore, and Dinajpur during 2018 and 2019 (Table 3). The highest leaf yield (14.0 tha^{-1}), fruit yield (51.21 tha^{-1}), and calyx yield (25.42 tha-1) were obtained at Manikganj, Jessore, and Jessore, respectively. The mean yield performance of the two years showed that the variety ME-4 gave a higher 7.25% leaf yield, 11.51% fruit yield, and 10.49% calyx yield than the check variety (Table 4). Overall, the yield performance of BJRI Mesta 4 was outstanding in all BJRI stations.

Table 3. Mean performance for yield traits of individual location

Trait	Locations							
	Manikganj	Kishanganj	Rangpur	Faridpur	Jessore	Dinajpur	Mean	LSD
PP (Lha^{-1})	1.83b	1.72b	1.77b	2.39a	2.37a	2.06ab	2.02	0.4159
Plant height (m)	2.38a	1.35b	2.38a	1.73ab	1.93ab	1.87ab	1.94	0.6668
No. of Leaves/pl.	21.33b	39.83a	23.50b	39.45a	19.05b	23.48b	27.77	15.413
Leaf wt./pl (gm)	61.05ab	42.13c	62.98a	58.27abc	53.17abc	43.92bc	53.59	18.436
No. of Branches/pl.	7.67ab	3.28c	6.35b	7.57ab	9.50a	6.53b	6.82	2.5079
No. of Fruits/pl	33.50a	17.32b	32.90a	20.13b	27.97ab	26.97ab	26.46	11.491
Single fruit wt (gm)	6.28c	6.16c	7.09ab	6.617bc	7.46a	7.76a	6.90	0.8111
Single calyx wt. (gm)	3.04d	3.11cd	3.50abc	3.39bcd	3.70ab	3.86a	3.43	0.4612
Leaf Yield (tha^{-1})	11.18ab	7.05c	10.92ab	13.27a	12.29a	8.85bc	10.59	2.9533
Fruit yield (tha^{-1})	38.82ab	17.49c	40.93ab	31.31bc	49.62a	42.93ab	36.85	16.448
Calyx yield (tha^{-1})	19.03ab	8.84c	20.22ab	16.09bc	24.59a	21.30ab	18.35	8.3125

Table 4. Yield performance (t/ha) of two verities at different agroecological zones during 2018-2019

Locations	Yield components	2018		2019		Mean over years	
		BJRI Mesta 4	BJRI Mesta 2	BJRI Mesta 4	BJRI Mesta 2	BJRI Mesta 4	BJRI Mesta 2
Manikganj	Leaf	12.89	9.15	11.93	10.76	12.41	9.96
	Fruit	49.39	37.92	35.23	32.74	42.31	35.33
	Calyx	24.73	18.64	19.14	14.18	21.94	16.41
Kishoreganj	Leaf	7.00	5.59	8.90	6.72	7.95	6.16
	Fruit	21.5	16.91	17.28	14.25	19.39	15.58
	Calyx	11.27	8.87	9.42	6.37	10.35	7.62
Rangpur	Leaf	12.36	11.07	9.86	10.39	11.11	10.73
	Fruit	52.02	45.50	35.78	30.42	43.90	37.96
	Calyx	19.4	21.39	17.42	15.43	18.41	18.41
Faridpur	Leaf	15.72	12.45	14.22	10.69	14.97	11.57
	Fruit	37.87	29.14	35.45	22.78	36.66	25.96
	Calyx	19.9	14.80	16.92	12.74	18.41	13.77
Jashore	Leaf	14.79	12.61	11.61	10.15	13.20	11.38
	Fruit	52.79	52.07	45.21	48.41	49.00	50.24
	Calyx	25.88	16.23	22.04	34.21	23.96	25.22
Dinajpur	Leaf	10.12	9.17	8.30	7.81	9.21	8.49
	Fruit	48.35	40.53	37.69	37.69	43.02	39.11
	Calyx	24.23	21.22	21.25	18.50	22.74	19.86
Mean over stations	Leaf	12.15	10.01	10.80	9.42	11.48	9.71
	Fruit	43.65	37.01	34.44	31.05	39.05	34.03
	Calyx	20.90	16.86	17.70	16.91	19.30	16.88

Legend: Yield increased in leaf (18.14%), fruit (14.74%) and calyx (14.33%)

Broad-sense Heritability, Genetic Advance, and Genetic Analysis

Estimates of genotypic (σ^2g), phenotypic (σ^2p), and error (σ^2e) variances ranged from 0.15 to 295.76, 0.25 to 504.08, and 0.10 to 258.64, respectively, in Table 5. The number of leaves per plant, the number of branches per plant, the number of fruits per plant, the yield of fruits, and the yield of calyxes all showed high phenotypic, genotypic, and error variance. Plant population, height, the number of leaves per plant, the weight of a single fruit or calyx, and leaf production all showed low genotypic and phenotypic diversity.

Table 5: Means squares of sources of variance for 11 quantitative parameters of the mesta genotypes of vegetables

Traits	Mean	σ^2_p	σ^2_g	σ^2_e	PCV (%)	GCV (%)	h^2_B (%)	GA (%)
Plant population (Lha^{-1})	2.02	0.25	0.15	0.10	24.52	19.03	60	30.44
Plant height (m)	1.94	0.48	0.23	0.25	35.83	24.83	48	35.46
Leaves/plant	27.77	11.03	7.24	3.79	48.73	39.48	66	65.91
Leaves wt./plant	53.59	262.87	130.11	132.77	58.37	41.06	49	59.52
Branches/plant	6.82	383.37	124.73	258.64	35.79	20.42	33	23.99
Fruits/plant	26.46	206.08	105.19	100.89	53.68	38.35	51	56.45
Single Fruit wt. (gm)	6.90	1.11	0.72	0.39	15.28	12.27	65	20.31
Single Calyx wt. (gm)	3.43	0.30	0.16	0.13	15.88	11.80	55	18.06
Leaf yield (tha^{-1})	10.59	17.34	8.84	8.49	38.49	27.49	51	40.45
Fruit yield (tha^{-1})	36.85	504.08	295.76	208.32	59.96	45.93	59	72.47

Calyx yield (tha^{-1})	18.35	122.62	69.27	53.34	59.44	44.67	57	69.17

Legend: σ^2_p, phenotypic variation; σ^2_g, genotypic variation; σ^2_e, error variation; PCV, phenotypic coefficient variation; GCV, genotypic coefficient variation; h^2_B, broad-sense heritability; GA, genetic advance.

Estimates of the phenotypic (PCV) and genotypic coefficients of variation (GCV) ranged from 15.28% to 59.96% and 11.80% to 45.93%, respectively. The highest PCV was recorded in the fruit yield (59.96%), followed by calyx yield (59.44%) and leaves weight per plant (58.37%). Similarly, the highest GCV was observed in fruit yield (45.93%), followed by calyx yield (44.67%) and leaves weight per plant (41.06%), highlighting the significant genotypic diversity of these traits and the potential for additional selection. This study's broad-sense heritability ranged from 33% (branches per plant) to 66% (leaves per plant). The three traits that showed high heritability (≤60%) are plant population, leaves per plant, and single fruit weight. The remaining characteristics are moderate heritability (30–60%) values. Regarding the 11 quantitative features, fruit yield had the largest genetic advance (72.47%), followed by calyx yield (69.17%). Single calyx weight (18.06%) and single fruit (20.31%) had the lowest values.

Relationship between Characteristics

The yield and yield component traits' straightforward Pearson phenotypic correlation coefficients were examined using the proc corr SAS software version 9.4, as shown in Table 6. Most characteristics don't exist in isolation; instead, they are linked in intricate relationships that eventually affect the yield. This connection might be favorable or unfavorable. The correlation coefficient (r-value) explains the link between two traits by identifying an association. Characters' phenotypic correlation coefficients ranged from 0.05 to 1.00, indicating more significant phenotypic variation. The R-values of 1, 0, and 1 show no perfect positive or negative linear relationship. According to Oladosu et al. (2018), the values between 0.7 and 1, 0.3 and 0.7, and 0 to 0.3 represent strong, moderate, and low positive linear relationships, respectively. In contrast, the values between -0.7 and -1, -0.3 and -0.7, and -0 to -0.3 represent strong, moderate, and low negative linear relationships, respectively.

There was a significant to moderately favorable phenotypic connection between leaf yield and leaf weight per plant, fruit production and fruits per plant, and calyx yield and fruit yield. However, there was a discrepancy between the number of leaves per plant and the production of fruit and calyx. Table 6 shows additional correlation coefficients between trait pairs of interest and vegetable mesta plant breeders.

Table 6: Analysis of 11 quantitative variables from the vegetable mesta genotypes combined across two crop seasons to determine the correlation coefficient

Traits	Plant height	No. of Leaves/plant	Leaf wt./plant	No. of Branches/plant	No. of Fruits/plant	Single fruit wt	Single calyx wt.	Leaf Yield	Fruit yield	Calyx yield

Plant population	-0.352^{*}	0.168^{ns}	-0.385^{*}	0.186^{ns}	-0.231^{ns}	0.078^{ns}	0.106^{ns}	0.310^{ns}	0.272^{ns}	0.285^{ns}
Plant height		-0.356^{*}	0.822^{**}	0.348^{*}	0.625^{**}	0.168^{ns}	0.131^{ns}	0.558^{**}	0.377^{*}	0.368^{*}
Leaves/plant			-0.054^{ns}	-0.426^{*}	-0.310^{ns}	-0.103^{ns}	0.061^{ns}	0.088^{ns}	-0.280^{ns}	-0.238^{ns}
Leaf wt./plant				0.364^{*}	0.460^{**}	0.184^{ns}	0.180^{ns}	0.749^{**}	0.213^{ns}	0.215^{ns}
Branches/ plant					0.340^{*}	0.182^{ns}	0.112^{ns}	0.504^{**}	0.436^{**}	0.419^{**}
Fruits/pl						0.318^{ns}	0.287^{ns}	0.283^{ns}	0.827^{**}	0.818^{**}
Single Fruit wt.							0.966^{**}	0.245^{ns}	0.575^{**}	0.582^{**}
Single Calyx wt.								0.259^{ns}	0.540^{**}	0.567^{**}
Leaf yield									0.388^{*}	0.400^{*}
Fruit yield										0.997^{**}

Legend: **Highly significant at 1% probability level; *Significant at 5% probability level; ns, insignificant.

Socio-economic Importance

Vegetable Mesta leaves can be cooked and eaten as a curry. According to Islam et al. (2016), fresh leaves and calyx make salads, tea, jams, and many other items. Its fleshy pods are used fresh to make confectionery foods such as juice, jam, jelly, syrup, gelatin, pudding, cake, ice cream, and dried in tea and spices (Mollah et al., 2020). Since vegetable mash contains pectin, jam can be easily made with sugar and sugar; there is no need to mix pectin separately. This fruit is widely used in making jam in Australia, Burma, and Trinidad. Chukur is known as a popular vegetable in Myanmar. The dried calyx is also used to make hot and cold drinks, food coloring, and vegetable mesta calyx tea, which can be used instead of herbal tea (Mollah et al., 2020). In Italy, Africa, and Thailand, the leaves of the vegetable Mesta are used to make herbal teas. Rosella tea, which lowers cholesterol and blood pressure and protects against cardiovascular disorders, is the most significant application of the vegetable Mesta Vrti. In addition to being an anti-inflammatory, anti-diabetic, and digestive help, rosella tea also lowers the risk of developing cancer.

According to Karma and Chavan (2016), edible oil production, poultry farming, and bakery are just a few businesses that use vegetable mesta seeds extensively. Mesta oil is used in many countries to make soaps and is added to cooking oil. Various dishes use the seeds, leaves, fruits, and roots of vegetables as well as other components of the plant. Tender leaves of Mesta are used to prepare curry (or) chutney in several parts of the country. The fleshy calyx (sepal) enveloping the fruit (capsule), which is used to make wine, juice, jam, jelly, syrup, gelatin, pudding, cakes, ice cream, pickles, tea, drink, and other confections, is one of them and is the component of the plant that has the most commercial importance. The green leaves and fruit pericarp are used like a spicy version of spinach. Leaves can also be used as tea/beverage.

The fleshy calyx (sepal), used to make various confectionaries, including juice, jam, jelly, syrup, drinks, gelatin, ice cream, tastes, etc., is the most significant plant component in terms of commerce (Figure 3). Tender leaves are used to prepare curry (or) chutney. Its attractive color, unique sour taste, and multi-purpose uses made it famous worldwide. These findings serve as a foundation for recommending new varieties for commercial cultivation in the herbal food product industry and adding them to the human diet to boost immunity.

The vegetable Mesta is cultivated commercially in many countries and is very popular as a food. Adivasis living in hilly areas can be seen cultivating vegetable Mesta commercially in or around the yard and in Chittagong Hill Tracts. Due to its high vitamin C and anthocyanin levels, vegetable mesta is special in nutrition (Islam et al., 2016). Being rich in various medicinal properties, including antioxidants and vegetable mesta, will play a helpful role in meeting people's nutritional needs, curing chronic diseases, and increasing the body's immune system (Morton, 1987).

Figure 3: BJRI Meta 4 multi-purpose uses with fresh vegetables and confectionery foods

Discussion

Significant differences in the features can speed up the identification and classification of separate lines during breeding operations (Akinrotimi and Okocha 2018). Plant breeders can choose genotypes for future breeding programs using the knowledge produced through qualitative traits-based variability. This investigation showed significant diversity between the two types for various morphological features. Wide variation was observed in stem and fruit calyx, where green stem with purple nodes was observed in BJRI Mesta 4, whereas purple color stem was observed in BJRI Mesta 2. The fruit calyx of BJRI Mesta 4 is green at the early stage but slightly pinkish pigmented at maturity, whereas the check variety (BJRI Mesta 2) has dark red fruit calyx. It was also mentioned that both vegetable mesta varieties differ in plant type, leaf shape, flower, and fruit color (Figure 1).

The 11 separate morpho-physiological variables from the combined quantitative data of the two years showed a significant difference (Table 2). Ibrahim and Hussein (2006) observed genotypic variations in the yield components of *H. cannabinus* and *H. sabdariffa.*

Differences between the characteristics' minimum and maximum values demonstrated the presence of variability between the two kinds. In their 2006 report, Ibrahim and Hussein discussed the variation in H. sabdariffa L. plant height and the number of capsules produced per plant. Nearly all of the characteristics had significant coefficients of variation (CV%), a measure of population variance. The findings of the univariate analysis show that the analyzed rosella types have a great deal of variability.

Yield is a complex character in any crop, governed by several factors. The development of high-yielding variety is essential for migrating the total production of vegetable mesta and its cultivation in the marginal land of Bangladesh. Out of six BJRI stations in six different AEZs of the country, the yield of fruit and calyx of the new variety BJRI Mesta 4 was higher in all the locations. The highest fruit yield (51.21 tha^{-1}) and calyx yield (25.42 tha^{-1}) of BJRI Mesta 4 were found in Jessore station, followed by Manikganj and Dinajpur station. The leaf yield of BJRI Mesta 4 was found to be higher in almost all the stations but lower in Dinajpur. The mean yield performance of BJRI Mesta, 4 over locations and years, was 11.16 tha^{-1} leaf yield, 35.93 tha^{-1} fruit yield, and 18.03 tha^{-1} calyx yield, which was 2.86%, 11.20%, and 14.04% higher than that of the check variety respectively.

The majority of genotypes had GCV values greater than 20%, except for plant population (19.03), single fruit weight (12.27), and single calyx weight (11.80). Low GCV indicated that the environment impacted how those phenotypes were expressed. The fact that PCV in every instance was larger than GCV suggests that the degree to which environmental factors affect phenotypic expression varies. As a result, there is a solid foundation for phenotypic selection that focuses on traits that are less impacted by the environment. Indicating the presence of a significant influence of additive gene action on the inheritance of these traits, high genetic progress and heritability were seen for plant population, leaves per plant, and single fruit weight. However, considerable genetic progress and moderate heritability were found for plant height, leaf weight per plant, branches per plant, fruits per plant, and yields of leaves, fruits, and calyxes. Selecting characteristics with high GCV, GA, and heritability is crucial.

Plant height, leaf weight per plant, and the number of branches per plant all significantly and positively correlated with the leaf yield. This study proved that branches per plant, fruits per plant, single fruit weight, and single calyx weight correlated considerably with fruit and calyx yield. Moreover, both fruit and calyx yield showed a positive and significant correlation between plant height and leaf yield. Fruit and calyx yield exhibited a strong positive connection (1.0).

According to Webber, Bhardwaj, and Bledsoe (2002), early maturity may reduce production per plant because early flowering and maturity result in short plants since early flowering inhibits vegetative development. The negative association between the number of leaves per plant, fruit production, and calyx yield supports this. Typically, genotypes with early flowering produce more fruit than late flowering ones. Regarding leaf, fruit, and calyx yield, the findings demonstrate that BJRI Mesta 4 beat the control variety BJRI Mesta 2.

Vegetable Mesta production is appropriate for tropical and sub-tropical climates that are warm and humid (Ansari et al., 2013). For developing the new variety, a dedicated screening of germplasms was carried out to determine their suitability for growing in the climate context of Bangladesh and select the most promising accession in production. The yield trial showed a remarkable yield increase in leaf, fruit, and calyx. Moreover, the new cultivar performed better than the check-in in most locations, which implied higher adaptability. The mean yield performance of the years 2018 and 2019 showed that the variety BJRI Mesta 4 gave 11.16 tha^{-1} leaf yield, 35.93 tha^{-1} fruit yield, and 18.03 tha^{-1} calyx yield, which is respectively 2.86%, 11.20% and 14.04% higher than that of the check variety. Therefore, it can be said that BJRI Mesta 4 has higher yield potential and adaptability and can be recommended for growing all over the country.

Except for the plant population (15.45%), the weight of a single fruit (12.27%), and the weight of a single calyx (11.80%), most genotypes displayed GCV values greater than 20%. Low GCV indicated that the environment impacted how they expressed their phenotype. Every time, PCV was larger than GCV, demonstrating that different environmental conditions influence how phenotypic expression is described. As a result, there is a solid foundation for phenotypic selection that focuses on traits that are less impacted by the environment. Plant population, leaves per plant, and single fruit weight all showed substantial genetic progress and heritability, indicating a significant role for additive gene activity in the inheritance of these traits. However, most variables, except for single calyx weight, show substantial genetic progress and moderate heritability. Choosing traits with a high GCV, GA, and heritability is crucial.

The new cultivar contained high levels of antioxidant activity, indicating possible usefulness as a beneficial vegetable in the human diet (Mollah et al., 2020). Therefore, based on the nutritional and medicinal properties studied, both cultivars can be used to promote the nutraceutical and pharmaceutical industries. However, several investigations claimed that the vegetable Mesta genotypes show changes in vitamins and mineral levels along with agro-climatic conditions and soil type (Atta et al., 2013; Islam, 2019). The method used to analyze the study's contents might also be a factor for this variation. This issue could be the subject of further research.

Different agroecological zones suggested that the line is better than the check variety concerning yield. Moreover, it is well recognized that the number of branches per plant is one of the important parameters for leaf, fruit, and calyx yield. The line ME-4 had produced a higher plant height than the check variety VM-1 in all stations. The finding suggested that the advanced line BJRI Mesta-4 has the potential for getting a higher yield.

Conclusion

BJRI Mesta 4 is a highly productive, adaptable, and nutritive multi-purpose crop that can potentially increase small farmers' income. One of the most underutilized crops, its importance in our nation is still underappreciated. The combined examination of the qualitative data revealed four characteristics that set the genotypes apart from the control variety. The selection of a better vegetable mesta genotype will be aided by the highly significant and favorable relationships of the key features with other agronomic traits, such as leaf yield, fruit yield, and calyx yield. The global trade roadmap predicts that the market for vegetable mesta will triple over the next five years as people become more aware of natural herbal products. It is, therefore, time to recognize vegetable mesta's potential in Bangladesh and encourage its varied applications. Both BJRI cultivars investigated and compared were discovered to have promising yield capacity, varied confectionery uses, and antioxidant qualities with various health advantages. However, considering the adaptability and yield potentiality, the novel variety BJRI Mesta 4 can be suggested for commercial production and contribute to the human diet for food security. This evaluation might help create trustworthy selection indices for favorable agronomic features in vegetable mesta. It is recommended that vegetable Mesta genotypes show changes in vitamins and mineral levels along with agro-climatic conditions and soil type, which should be explored in future research to establish the study's contents, which might also be a factor for this variation.

Conflicts of Interest

The author(s) declared no conflict of interest.

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