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RESEARCH ARTICLE

BJRI Mesta 4: A newly released improved vegetable Mesta variety of Hibiscus sabdariffa L.

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Abstract

Vegetable mesta, also known as 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 that was 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 ($p \leq 0.01$ or 0.05) were recorded among the qualitative and quantitative traits. It also possesses in Multi-location Trials during 2018 and 2019, the average yield of leaf, fruit and calyx of BJRI Mesta 4 was found 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 taken into consideration during selection to create vegetable mesta types with appropriate yield. 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 kept in mind, the study that has been conducted now may help in creating trustworthy selection criteria for programs to improve vegetable mesta breeding in the future.

Keywords: Vegetable mesta; roselle; leaf; calyx; yield; herbal

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. sabdariffa (Sobhan, 1993). The edible variety is a short bushy plant (1 - 2 m) bearing profuse smooth fruits popularly known as roselle or rosella (Dempsey, 1975). Its fleshy calyx and epicalyx is 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). The production cycle of this plant lasts around six months. There are more than 300 roselle species that are found all over the world (Balarabe, 2019). Mesta is a time-bound plant which means 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 and unique sour taste along with its multi-purpose uses made it popular around the world (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 greatest commercial significance. The green leaves and fruit pericarp are used like a spicy version of spinach. Leaves can also be used as tea/beverage (Islam et. al, 2021). 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 was recently developed by the Bangladesh Jute Research Institute. 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 (Sanders et al., 2023). Given this information, an effort was made in the year 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 bearing higher yield potentials, adaptability and a considerable number of antioxidants may improve its acceptance to consumers, which would eventually strengthen the nation's economy. Utilization of marginal and fallow land to produce BJRI Mesta 4 increases women's involvement in agriculture in Bangladesh by selling fresh vegetables and confectionaries around the year. Similar to this, 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 gain this knowledge. The identification of potential genotypes for commercial cultivation is therefore made more challenging.

Materials and Methods

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 carried out using an RCB design (Chowdhury et.al, 2024), with 3 replications in each plot's 60 m^2 effective area. The advanced line ME-4 (BJRI Mesta 4) and the check variety BJRI Mesta 2 were each given an equal piece of a 10-decimal plot in six different Jute Research Regional Stations. Agronomic trials were also conducted in different locations. 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 (2018 and 2019). Intercultural operations such as thinning, weeding, agronomic techniques, and supplemental irrigations were completed simultaneously for entire plots as recommended by Chowdhury and Hassan (2013). 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, and 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. At the seedling and growth stages in the field, the qualitative characteristics including stem color and leaf shape were observed visually. 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, and 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 (Tareq et al., 2021; Al-Mamun et al., 2022a).

Table 1. Quantitative characters studied from vegetable mesta genotypes

Traits	Denotation	Description
Plant population (Lha^{-1})	PP	Number of plants of 5 decimal or 200 square mitres were counted at the time of harvest.
Plant height (m)	PH	At the time of harvest, the height in meters from the soil's surface to the tips of 15 randomly chosen plants was measured.
Leaves/plant	L	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 weight/plant	LWt	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	Br	To determine the average branch number per plant, the number of branches on 15 randomly chosen plants was counted.
Fruits/plant	Fr	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 weight (gm)	SFrW	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)	SCw	The average weight of calyx from randomly selected fruit of each replication was weighted on electric balance and the reading.
Leaf yield (tha^{-1})	LY	The leaf yield data were calculated as follows: Weight of leaves/plant × Plant population/ha
Fruit yield (tha^{-1})	FrY	The fruit yield data were calculated as follows: Weight of fruits/plant × No. of fruits/plant × Plant population/ha
Calyx yield (tha^{-1})	CY	The calyx yield data were calculated as follows: Weight of calyces/fruit × No. of fruits/plant × Plant population/ha

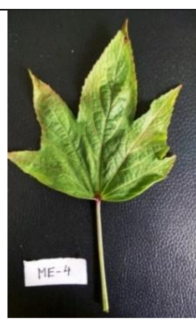
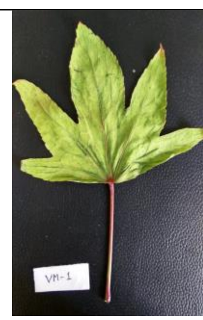
Data analysis

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 (σ2g), phenotypic (σ2p) and error (σ2e) 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.

Results

Qualitative variation

The new variety BJRI Mesta 4 is bushy and shorter than the check variety BJRI Mesta 2 with a higher number of branches and higher biomass (Mostofa, et al., 2022). The new variety is comparatively dwarf and branching type and is almost resistant to diseases and pests (Mostofa, et al., 2022). The variety BJRI Mesta 4 is morphologically different from the check one by its stem (Figure 1b) and fruit color (Figure 1c). It possesses a larger fruit size with fleshy calyces (Figure 1d). 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)
(a) 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.

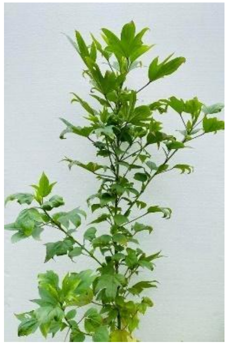
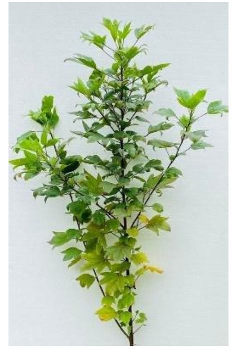
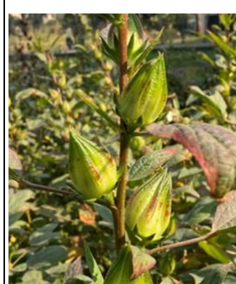
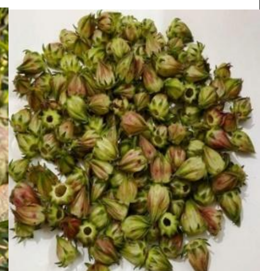
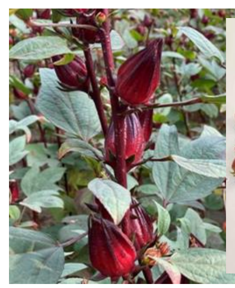
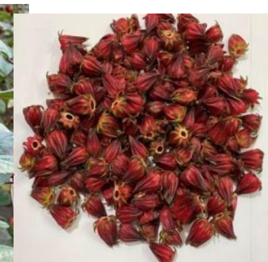
(b) Stem color	 It has a green and smooth stem with purple nodes	 BJRI Mesta 2 has a smooth and purple stem
(c) Flower color	 Cream color with red center	 Cream-colored flowers
(d) Fruit and fruit calyx	  Fruit capsule (pointed) and reddish green in color. Its fruit calyx is green at the early stage but slightly pinkish pigmented at maturity.	  Fruit capsule (pointed) and red. Dark red fruit calyx.

Figure 1. Some qualitative Characters' of BJRI vegetable mesta genotypes (a) Plant type and leaf shape variation, (b) Stem color variation, (c) Flower color variation, (d) Fruit and fruit calyx variation.

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 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 in 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

S.O.V	Replication	Locations	Genotypes	Gen*Location	Error	Mean±Std error	CV (%)
DF	2	5	1	5	22		
PP	0.47*	0.54**	0.00	0.02	0.12	2.02±0.07	21.11
PH	0.25	0.95*	0.17	0.01	0.31	1.94±0.10	30.50
L	34.61	523.08*	32.51	7.98	165.70	27.77±2.25	48.70
LWt	393.42	468.96	4.98	19.86	237.08	53.59±2.59	29.00
Br	48.89**	25.52**	3.74	1.17	4.39	6.82±0.51	45.15
Fr	193.72	260.63*	70.28	1.52	92.10	26.46±1.74	39.35
SFrW	0.05	2.54**	0.21	0.15	0.46	6.90±0.14	11.97
SCw	0.04	0.63**	0.20	0.05	0.15	3.43±0.07	12.96
LY	6.20	31.31**	0.59	0.57	6.08	10.59±0.49	27.93
FrY	139.05	751.26*	205.35	8.04	188.71	36.85±2.59	42.12
CY	28.59	176.67*	71.60	2.51	48.20	18.35±1.29	42.07

Note: *Significant at 0.05 probability level; **highly significant at 0.01 probability level; df, degrees of freedom; SOV, Source of variation; CV, Coefficient of variation; Std error, standard error; PP, Plant population (Lha-1); PH, Plant height (m); L, No. of Leaves/plant.; LWt, Leaf weight/plant (gm); Br, No. of Branches/plant; Fr; No. of Fruits/plant; SFrW, Single fruit weight (gm); SCw, Single calyx weight (gm); LY, Leaf Yield (tha^{-1}); FrY, Fruit yield (tha^{-1}); CY, Calyx yield (tha^{-1}).

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 are summarized in 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	1.83^{b}	1.72^{b}	1.77^{b}	2.39^{a}	2.37^{a}	2.06^{ab}	2.02	0.4159
PH	2.38^{a}	1.35^{b}	2.38^{a}	1.73^{ab}	1.93^{ab}	1.87^{ab}	1.94	0.6668
L	21.33^{b}	39.83^{a}	23.50^{b}	39.45^{a}	19.05^{b}	23.48^{b}	27.77	15.413
LWt	61.05^{ab}	42.13^{c}	62.98^{a}	58.27^{abc}	53.17^{abc}	43.92^{bc}	53.59	18.436
Br	7.67^{ab}	3.28^{c}	6.35^{b}	7.57^{ab}	9.50^{a}	6.53^{b}	6.82	2.5079
Fr	33.50^{a}	17.32^{b}	32.90^{a}	20.13^{b}	27.97^{ab}	26.97^{ab}	26.46	11.491
SFrW	6.28^{c}	6.16^{c}	$7.09a^{b}$	6.617^{bc}	7.46^{a}	7.76^{a}	6.90	0.8111
SCw	3.04^{d}	3.11^{cd}	3.50^{abc}	3.39^{bcd}	3.70^{ab}	3.86^{a}	3.43	0.4612
LY	11.18^{ab}	7.05^{c}	10.92^{ab}	13.27^{a}	12.29^{a}	8.85^{bc}	10.59	2.9533
FrY	38.82^{ab}	17.49^{c}	40.93^{ab}	31.31^{bc}	49.62^{a}	42.93^{ab}	36.85	16.448
CY	19.03^{ab}	8.84^{c}	20.22^{ab}	16.09^{bc}	24.59^{a}	21.30^{ab}	18.35	8.3125

Note: LSD, Least Significant Difference; PP, Plant population (Lha-1); PH, Plant height (m); L, No. of Leaves/plant.; LWt, Leaf weight/plant (gm); Br, No. of Branches/plant; Fr; No. of Fruits/plant; SFrW, Single fruit weight (gm); SCw, Single calyx weight (gm); LY, Leaf Yield (tha^{-1}); FrY, Fruit yield (tha^{-1}); CY, Calyx yield (tha^{-1}); Mean values are explained for each trait and upper-case letter show significance.

Table 4. Yield performance (t/ha) of two varieties at different agro-ecological 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

Note: Yield increased in leaf (18.14%), fruit (14.74%) and calyx (14.33%) compared to the check variety.

Broad-sense heritability, genetic advance, and genetic analysis

Estimates of genotypic (σ^2g), phenotypic (σ^2p), and error (σ^2e) variances ranging from 0.15 to 295.76, 0.25 to 504.08, and 0.10 to 258.64, respectively, are presented in Table 5.

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

Traits	Mean	σ2p	σ2g	σ2e	PCV (%)	GCV (%)	h2B (%)	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/pla nt	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/plan t	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

Note: 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.

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. 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. In this study, 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 rest of the traits are observed in moderate heritability (30–60%) values. In terms of 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; rather, they are linked to one another in intricate relationships that eventually affect the yield. This connection might be favorable or unfavorable. By identifying an association, the correlation coefficient (r-value) provides an understanding of the link between two different traits. Characters' phenotypic correlation coefficients ranged from 0.05 to 1.00, indicating greater phenotypic variation. There is no linear relationship, a perfect positive linear relationship, and a negative linear relationship, respectively, according to the r-values of 1, 0, and 1. 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. In Table 6, additional correlation coefficients between trait pairs of interest to vegetable mesta plant breeders are shown.

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

Traits	PH	L	LWt	Br	Fr	SFrW	SCw	LY	FrY	CY
PP	-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}
PH		-0.356*	0.822**	0.348*	0.625**	0.168^{ns}	0.131^{ns}	0.558**	0.377*	0.368*
L			-0.054^{ns}	-0.426*	-0.310^{ns}	-0.103^{ns}	0.061^{ns}	0.088^{ns}	-0.280^{ns}	-0.238^{ns}
LWt				0.364*	0.460**	0.184^{ns}	0.180^{ns}	0.749**	0.213^{ns}	0.215^{ns}
Br					0.340*	0.182^{ns}	0.112^{ns}	0.504**	0.436**	0.419**
Fr						0.318^{ns}	0.287^{ns}	0.283^{ns}	0.827**	0.818**
SFrW							0.966**	0.245^{ns}	0.575**	0.582**
SCw								0.259^{ns}	0.540**	0.567**
LY									0.388*	0.400*
FrY										0.997**

Legend: PP, Plant population (Lha-1); PH, Plant height (m); L, No. of Leaves/plant.; LWt, Leaf weight/plant (gm); Br, No. of Branches/plant; Fr; No. of Fruits/plant; SFrW, Single fruit weight (gm); SCw, Single calyx weight (gm); LY, Leaf Yield (tha^{-1}); FrY, Fruit yield (tha^{-1}); CY, Calyx yield (tha^{-1}); **Highly significant at 1% probability level; *Significant at 5% probability level; ns, not significant.;

Socio-economic Importance

The fleshy calyx (sepal), which is 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 for preparing curry (or) chutney. The overall attractive color and unique sour taste of this crop along with its multi-purpose uses made it popular around the world. These findings serve as a foundation for recommending the new variety for commercial cultivation in the herbal food product industry as well as adding to the human diet for boosting immunity.

Figure 3. BJRI Mesta 4 multipurpose uses with fresh vegetables and confectionery foods

Discussion

Major differences in the features can speed up identifying and classifying separate lines during breeding operations (Akinrotimi and Okocha 2018). Plant breeders can choose genotypes for future breeding programs with the use of the knowledge produced through qualitative traits-based variability. For various morphological features in this investigation, there was significant diversity between the two types. 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 and 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 the characteristics had large 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 which is governed by several factors. The development of high-yielding variety is essential for migrating the total production of vegetable mesta and also for 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 found 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, respectively. The leaf yield of BJRI Mesta 4 was found 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. Most 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 had an impact on 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 together with high heritability was seen for plant population, leaves per plant, and single fruit weight. For plant height, leaf weight per plant, branches per plant, fruits per plant, and yields of leaves, fruits, and calyxes, however, considerable genetic progress and moderate heritability were found. 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 were highly significantly correlated with fruit yield and calyx yield. Moreover, fruit yield and calyx yield both showed a positive and significant correlation with plant height and leaf yield. Fruit yield and the calyx yield exhibited a strong positive connection (1.0). According to Webber et al. (2002), early maturity may reduce production per plant because early flowering and maturity result in short plants since early flowering inhibits vegetative development. This is supported by the negative association between the number of leaves per plant and fruit production and calyx yield. Typically, genotypes with early flowering produce more fruit than genotypes with late flowering. In terms of 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 for their suitability to be grown in the climate context of Bangladesh to select the most promising accession in terms of production. The yield trial showed a remarkable yield increase in leaf, fruit and calyx. Moreover, the new cultivar performed better than the check in most of the locations which implicit 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 having higher yield potential and adaptability, 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 had an impact on how they expressed their phenotype. Every time, PCV was larger than GCV, demonstrating that different environmental conditions have various degrees of influence on how phenotypic expression is expressed (Al-Mamun et al., 2022a). 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 strong genetic progress and heritability, indicating a significant role for additive gene activity in the inheritance of these traits. However, most of the variables, except for single calyx weight, show substantial genetic progress and moderate heritability. Choosing traits with a high GCV, GA, and heritability (Al-Mamun et al., 2022b). Total four antioxidant components e.g., total phenol content, total flavonoid content, proanthocyanidin content, and anthocyanin content were measured from the calyx sample indicating possible usefulness as a beneficial vegetable in the human diet (Almajid et al., 2023; 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 (Sanders et al., 2023). 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 branches per plant are one of the important parameters for leaf, fruit and calyx yield. The newly released cultivar BJRI Mesta 4 produced a higher plant height than the check variety BJRI Mesta 2 in all stations. The finding suggested that the BJRI Mesta-4 has the potential to get a higher yield.

Conclusion

BJRI Mesta 4 is a highly productive, adaptable, and nutritive multipurpose crop that has the potential to increase the income of small farmers. 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 the potential of vegetable mesta in Bangladesh and to encourage its varied application. Both BJRI cultivars investigated and compared were discovered to have promising yield capacity, varied confectionery uses, and antioxidant qualities with a wide variety of health advantages. The novel variety BJRI Mesta 4 can be suggested for commercial production and contribute to the human diet for food security, however, considering the adaptability and yield potentiality. 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 should be explored in future research to establish the study's contents might also be a factor for this variation.

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