RESEARCH ARTICLE

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Genotypic Effects on Morphological Characterization of Fruit Traits in Mulberry

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ABSTRACT

The research was conducted to evaluate the morphological variability in fruits traits among the mulberry genotypes grown in Mulberry Germplasm Bank of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, during 2018–2020. The aim of the research was to find out the genotypes accessibility for varietal improvement. Total 50 mulberry genotypes were morphologically characterized on fruit traits through this research. The experimental design was Randomized Complete Block Design (RCBD) with three replications and the plantation system was high bush. Each plot consists of 20 plants and unit plot size was 4 m × 5 m. Fruit colour, fruit taste and seed colour was determined. Nine distinct fruit colours such as reddish-black (23.33%), black-berry (18.33%), cream (10%), black (8.33%), white-cream (6.67%), pink (6.67%), pinkish (3.33%), orange (3.33%) and radish (1.67%) were observed among several germplasms. Remarkable variation was found in fruit taste such as sour sweet (28.33%), sweet (21.67%), light sweet (5%), light-sour sweet (5%) and deep sweet (5%), respectively. Five colored of seed viz: light yellow, light brown, yellowish brown, dark brown and blackish brown were observed among the germplasm. Length of the fruit diverse from 0.73 (BSRM-8) to 5.58 (BSRM-56 and widthfrom 0.52 (BSRM-8) to1.9 (BSRM-56),single fruit weight varied from 0.07 (BSRM-8) to 4.11 (BSRM-56), fruit weight per plant varied from 101.47 (BSRM-11) to 2250.43 (BSRM-56), seed setting (%) varied from 8.13 (BSRM-29) to 94.24 (BSRM-16), sprouting (%) varied from 36.67 (BSRM-22) to 96.67 (BSRM-38), rooting (%) varied from 13.89 (BSRM-22) to 98.33 (BSRM-10),achene number/fruit varied from 12.53 (BSRM-10) to118.10 (BSRM-56), seed number/fruit varied from 2.99 (BSRM-8) to 47.86 (BSRM-56) and 100 seed weight varied from 0.019 (BSRM-35) to 0.166 (BSRM-56), respectively. Results showed that the black-berry, sweet tasted fruited mulberry (BSRM-56), cream colored, sweet tasted fruited mulberry (BSRM-1) and white cream, sweet tasted fruited mulberry (BSRM-34) was promising on the basis of greatest fruit production potential to be appears for further commercial utilization. Generally, a wide range of variation was exhibited among the sampled and characterized genotypes.

Keywords: Genotype, Promising, Seed Setting, Sericulture, Silkworm.

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I. Introduction

The mulberry (*Morus* spp.; Family- Moraceae) is an important Sericultural industry foliage plant for sole feed for silkworms and most of the research has been conducted on mulberry leaves. Because in sericulture sector mulberry fruit is considered of no use and a little study has focused on mulberry fruit. It is widely dispersed and can grow in a wide range of climatic, topographical, and soil conditions throughout the world by [1]. Mulberry is originated in the boundary area of the Indo-Chinese region and scattered in the lower slopes of the sub-Himalayan zone up to an elevation of 3300 m reported by [2]. In the world approach three main species, viz: white mulberry (*Morus alba*), red mulberry (*Morus rubra*), and the black mulberry (*Morus nigra*) are the commonly disseminated and used mulberries reported by [3]. These three major mulberry species originated from diverse areas of the world. However, in the Eastern United States red mulberry (the American mulberry) is native, white mulberry, bred for silkworm production and fruit cultivation, native to China and the black mulberry is native to Asia reported by [4]-[6].

Mulberry, an important commercial crop, is cultivated extensively for its foliage which is the sole food for domesticated silkworm, *Bombyx mori* including Bangladesh. Mulberry fruit contains various kinds of nutrient compounds viz: amino acids, minerals, and vitamins. Now, mulberry can also be utilized for catering of diversified requirements such as food, fodder, fuel, and fibre except only the solitary food of domesticated mulberry silkworm (*Bombyx mori*). The ripe mulberry fruits are decidedly cherished for their delicious taste, and which are also consumed either fresh or after extraction of juice. Due to contain of biologically active ingredients mulberry fruits might be associated with some potential pharmacological actions. Thus, mulberry fruits have a valuable impact on health benefits. Most of the mulberry-

growing countries of the world due to delicious taste, pleasing colour, low calorie and high nutrient content of mulberry fruit it is usually eaten as fresh, dried, or processed into wine, fruit juice, and jam for [3],[7],[8]. Currently berries crops have gained enormous implication due to their value in the diet vis-a-vis human health as they are prosperous sources of antioxidant [9] which are vastly dependent on the genotypes [10]. Especially in European countries mulberry fruit has recognized as 'superfood' status due to the presence of bioactive compounds reported by [11]-[14].

In Bangladesh generally a number of mulberry cultivars are grown only as a solitary feed for mulberry silkworm rearing. In present situation mulberry cultivation is beginning popular as an edible food over the world but in Bangladesh it is a totally new scheme. However, in very recent the people of Bangladesh are being interested to growing mulberry as an edible food for its high nutrient content, tasty, content low calorie, pleasant colour, health benefits as well as financially viable benefits. Now mulberry grown practically more or less all over the country but the fruit production of these varieties or cultivars is comparatively low due to the lack of introducing of improved fruiting variety [15]. Characterization is the absolutely fundamental task to provide information for hybridization as well as breeding programs [16]. Knowledge of characterization and evaluation of the germplasm will help the further varietal improvement program. The reorganization of the variability and to improve the local germplasm and also easily as well as quickly evaluation of collected germplasm characterization is the obligatory task. Besides, a Plant breeder has relied over the years on phenotypic characterization for cultivation of a cultivar [17], [18]. The registration and protection of new cultivars morphological characterization is the official method reported by [19]. Different morphotypes of mulberry are existing in Bangladesh Plant Genectic Resources Centre (PGRC) of Bangladesh Sericulture Research and Training Institute (BSRTI) collected and conserved different types of mulberry germplasm from home and abroad. But the morphological characterization of mulberry germplasm on horticultural traits has not been conducted systematically. That's why, the present research was carried out to morphological characterize of mulberry germplasm to provide useful information on fruit traits for further breeding programs as well as to promote the use of these genetic resources.

II. Materials and Methods

A. Plant Material

The Mulberry Germplasm Bank of the Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh, recently are being maintaining 84 genotypes including wild and developed species under field condition. Among them, 50 fruit-using mulberry genotypes were characterized on morphological-traits (Table I).

B. Evaluation of Fruit Traits

The experiment was conducted at the Mulberry Gemrplasm Bank of BSRTI, Rajshahi. Five plants were transplanted from each genotype. The normal cultural practices viz: recommended doses of manure and fertilizers such as 15 MT/ha cowdung, N300P150K100 kg/ha per year with two split doses were applied in the experimental field [20]. The other cultural practices like- digging cum weeding, irrigation, pruning and disease-pest control were followed as per needed. Mulberry fruit traits, including fruit colour, taste, seed colour, fruit length, fruit width, single fruit weight, fruit weight/plant, seed setting%, sprouting%, rooting%, achene number/fruit, seed number/fruit and 100 seed weight, were evaluated during the fruit-growing season from five different plants for each genotype. Total thirteen (13) observations on qualitative (03) and quantitative (10) characters were recorded following the descriptor and acceptable to International Compendium Programme and International Board of Plant Genetic Resources (IBPGR) of [21] and [22].

TABLE I: List of Mulberry Germplasm Characterized during 2018 to 2020

Sl. No.	Germplasm/Genotypes name	Accession number	Remarks
1.	White mulberry	BSRM-1	Bangladesh local
2.	Black mulberry	BSRM-2	Bangladesh local
3.	Bombay	BSRM-3	Bangladesh local
4.	Bangla local	BSRM-4	Bangladesh local
5.	BM-1	BSRM-5	Bangladesh develop
6.	Bangla local	BSRM-6	Bangladesh local
7.	Bangla local	BSRM-7	Bangladesh local
8.	Tellia	BSRM-8	Bangladesh local
9.	Bangla local	BSRM-10	Bangladesh local
10.	Bangla local	BSRM-11	Bangladesh local
11.	Dudiya	BSRM-12	Bangladesh local
12.	Sadabombay	BSRM-13	Bangladesh local
13.	Lal bombay	BSRM-14	Bangladesh local
14.	Kanva-2	BSRM-15	Indian developed
15.	BM-4	BSRM-16	Bangladesh develop
16.	BM-2	BSRM-18	Bangladesh develop
17.	BM-3	BSRM-19	Bangladesh develop
18.	S-54	BSRM-20	Indian develop
19.	Jink	BSRM-21	China develop
20.	Lup-40	BSRM-22	China develop
21.	Indian local	BSRM-23	Idian local
22.	Bangla develop	BSRM-25	Bangladesh develop
23.	Bangla develop	BSRM-26	Bangladesh develop
24.	Bangla develop	BSRM-27	Bangladesh develop
25.	*Morus laevigata*	BSRM-28	Indigenous wilt
26.	Bangla develop	BSRM-29	Bangladesh develop
27.	Bangla develop	BSRM-30	Bangladesh develop
28.	Bangla develop	BSRM-33	Bangladesh develop
29.	BM-7	BSRM-34	Bangladesh develop
30.	Bangla develop	BSRM-35	Bangladesh develop
31.	Bangla develop	BSRM-36	Bangladesh develop
32.	Bangla develop	BSRM-37	Bangladesh develop
33.	Bangla develop	BSRM-38	Bangladesh develop
34.	S-30	BSRM-40	Indian develop
35.	S-36	BSRM-42	Indian develop
36.	BM-6	BSRM-45	Bangladesh develop
37.	MR-2	BSRM-46	Indian develop
38.	R-135	BSRM-47	Indian develop
39.	Kosen	BSRM-48	Japan develop
40.	Mijusawa	BSRM-49	Japan develop
41.	Multicaules	BSRM-50	Japan develop
42.	Bird-foot	BSRM-51	Indian develop
43.	Bangla wilt	BSRM-53	Bangladesh local
44.	China diploid	BSRM-54	China develop
45.	China triploid	BSRM-55	China develop
46.	BM-8	BSRM-56	Bangladesh develop
47.	BM-9	BSRM-58	Bangladesh develop
48.	OP-146	BSRM-59	Bangladesh develop
49.	V-5	BSRM-60	Indian develop
50.	China	BSRM-61	China develop

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C. Descriptor and Descriptor States

1) Qualitative Descriptor

Fruit colour (In the main flowering season data was recorded by selecting fully matured fruits in the longest shoot): In full ripen stage the colour of the fruits was recorded and graded on visual observation. Radish-black = 1, Black-berry = 2, Cream = 3, Black = 4, White-cream = 5, Pink = 6, Pinkish = 7,Orange = 8 and Radish = 9.

Fruit taste (Recorded in the main flowering season by selecting fully matured fruits in the longest shoot): The fruit taste was recorded when the fruits were full ripen stage. Here, Sour-sweet = 1, Sweet = 2, Light sweet = 3, Light-sour sweet = 4 and deep sweet = 5.

Seed colour (Seed colour was recorded in the main flowering season by selecting fully matured fruits in the longest shoot. After harvesting of seeds from the ripened fruits the seed colour was recorded by observing under the stereo microscope): Here, Light yellow = 1, Light brown = 2, Yellowish brown = 3, Dark brown = 4 and Blackish brown = 5.

2) Quantitative Descriptors

TABLE II: QUANTITATIVE DESCRIPTORS

SI. No.	Descriptor	Growth stage and time for data recording	Method
1.	Fruit length (cm)	Recorded in the main flowering season by selecting the fully matured fruits in the longest shoot	The data was recorded when the fruits were in full ripening stage. The length of the full fruits including the peduncle. Total randomly 9 fruits from three plants were considered collecting 3 fruits from a plant.
2.	Fruit width (cm)	Recorded in the main flowering season by selecting the fully matured fruits in the longest shoot	The data was recorded when the fruits were in full ripening stage. The breath of the full fruits including the peduncle. Total 9 fruits from three plants were considered collecting 3 fruits from a plant.
3.	Single fruit weight (g)	Recorded in the main flowering season by selecting the fully matured fruits in the longest shoot	The same fruits which were used for taking the data on length and breadth that were used for taking the weight of fruits individually.
4.	Fruit weight per plant (g)	Recorded in the main flowering season	The sum of the total fruit weight at different harvesting date was divided by number of plants to get yield (average) per plant.
5.	Seed setting (%)	Recorded in the main flowering season by selecting the fully matured fruits in the longest shoot	The data was recorded when the fruits were in full ripening stage. It was the ratio between total numbers of healthy seeds/fruit to the total number of achenes/fruits.
6.	Sprouting (%)	Recorded 20 days after plantation of cutting in earthen pot.	Percentage of sprouted cuttings out of total planted cuttings was counted manually.
7.	Rooting (%)	Rooting percentage was recorded based on the survival rate after 90 days of plantation.	Rooting percentage was recorded based on the survival rate after 90 days of plantation.
8.	Achene number/fruit	Recorded in the main flowering season by selecting the fully matured fruits in the longest shoot	Numbers of achenes/fruit were counted manually by separating the achenes from the sorosis.
9.	Seed number/fruit	Recorded in the main flowering season by selecting the fully matured fruits in the longest shoot	Separated achenes were crashed together by the finger tip and seeds were separated from the pulp by allowing standing in a tray containing water. Then the derbies from the tray were washed out and the number of seeds/fruit was counted manually.
10.	100 seed weight (g)	Recorded in the main flowering season by selecting the fully matured fruits in the longest shoot	Data was measured as average weight of 100 randomly selected oven dry seeds.

D. Statistical Analysis

Experimental data on fruit traits were analyzed of range, mean, SD and mean coefficient of variation (CV%) of quantitative characters were calculated using the analytic tools of Microsoft Excel software. Analysis of correlations between the fruits traits and associations among the genotypes by principal component analysis (PCA) was completed by applying the RStudio computer software.

III. RESULTS AND DISCUSSION

A. Qualitative Characters

Qualitative traits of fruits such as fruit colour, fruit test and seed colour exhibited distinct variations (Table II). The fruit colour showed the maximum variation. Nine categories of fruit colour such as reddish black (30%), blackberry (22%), cream (12%), black (10%), white cream (8%), pink (8%), pinkish (4%), orange (4%) and reddish (2%) were observed among the germplasm at maturity stage after 90 days of pruning. The reddish black colour fruits were markedly and black-berry was medium. The cream coloured fruits were observed in germplasm BSRM-1, BSRM-5, BSRM-25, BSRM-30, BSRM-33 and BSRM-51 and the black coloured fruit was found in germplasm BSRM-4, BSRM-18, BSRM-23, BSRM-27 and BSRM-58. These finding was lined with the previous finding of [8] who found the diverse colored fruits among the mulberry genotypes. They indentified three colour of mulberry fruits viz: black, white and red among the 93 genotypes with maximum colour was black. Similarly, they [23] determined the two colour of mulberry fruits among the 10 selected genotypes belonging to the 3 mulberry species (*Morus alba*, *Morus rubra* and *Morus laevigata*) viz: white colour and red colour but dominant was white colour. Likewise, fruit colour was varied greatly from white to black with diverse color shades upon ripening viz. white mulberries can produce white, lavender, or even black fruits depending, to certain extent, on the timing of harvest [24]. They also found that the over ripened white mulberry fruits turn into somewhat black due to delay of harvesting. Correspondingly, the coloring compounds tend to concentrate in the outer drupelets' cells in *Morus alba*, whereas in the fruits of *Morus*

nigra and *Morus rubra*, these substances concentrate in all the cells of drupelets [4]. In our studied germplasm nine colored of fruit was determined may be due to the variability of number of species and genetic diversity among these species. Fruit taste exhibited as sour-sweet, sweet, light-sweet, light-sour sweet, deep-sweet and sour categories respectively. Out of 50 germplasm 36% fruits were sour-sweet, 30% sweet, 16% light sweet, 6% light sour sweet, 6% deep sweet and 6% sour respectively in taste. However, sour sweet fruit was markedly and sweet fruit moderately in our studied germplasm (Table III). The recorded sour-sweet germplasm were BSRM-4, BSRM-8, BSRM-14, BSRM-15, BSRM-18, BSRM-20, BSRM-23, BSRM-31, BSRM-34, BSRM-35, BSRM-36, BSRM-38, BSRM-41, BSRM-43, BSRM-45, BSRM-47 and BSRM-50 as well as fruits of BSRM-1, BSRM-9, BSRM-11, BSRM-16, BSRM-21, BSRM-24, BSRM-28, BSRM-29, BSRM-30, BSRM-37, BSRM-40, BSRM-42, BSRM-46, BSRM-48 and BSRM-49 germplasm were sweet in taste (Table III).

This finding was also similar with previous finding of [4] who reported that fruits of White mulberry are generally very sweet; red mulberry fruits are sweet and usually deep red or almost black. Whereas, black mulberry fruits are attractive, large, and juicy, with a good balance of sweetness and tartness that makes them the best-flavored fruits in mulberry. Among the studied germplasm total five categories of seed colour was observed such as light yellow (38%), light brown (24%), yellowish brown (18), dark brown (4%) and blackish brown (16%) respectively at fully ripen stage (Table III) may be due to the unpredictable genetic characters of studied germplasm species which was corresponding with the previous finding of [15]. He reported four colour of seed viz: dark brown, light yellow, blackish brown and yellowish brown respectively among the 45 mulberry genotypes might be due to the unpredictability of mulberry species. The qualitative descriptors for individual germplasm are presented (Table IV).

TABLE III: MORPHOLOGICAL VARIABILITY OF 50 MULBERRY GERMPLASMS BASED ON QUALITATIVE FRUIT TRAITS DURING 2018-2020

SI. No.	Descriptor	Descriptor state	No. of germplasm	% of germplasm	Germplasm (Serial number in table I)
1.	Fruit colour	1.1 Reddish black	15	30	8, 12, 19, 20, 23, 33, 34, 35, 36, 38, 39, 43, 44, 45, 50
		1.2 Black-berry	11	22	2, 4, 6, 9, 10, 11, 14, 15, 18, 31, 46
		1.3 Cream	6	12	1, 5, 22, 27, 28, 42,
		1.4 Black	5	10	3, 16, 21, 24, 47
		1.5 White-cream	4	8	7, 29, 37, 48
		1.6 Pink	4	8	17, 30, 32, 40
		1.7 Pinkish	2	4	13, 25
		1.8 Orange	2	4	26, 41
		1.9 Reddish	1	2	49
2.	Fruit taste	2.1 Sour-sweet	18	36	4, 8, 12, 14, 15, 18, 20, 23, 31, 34, 35, 36, 38, 41, 43, 45, 47, 50
		2.2 Sweet	15	30	1, 9, 11, 16, 21, 24, 28, 29, 30, 37, 40, 42, 46, 48, 49
		2.3 Light- sweet	8	16	2,5, 7, 13, 22, 25, 26, 27,
		2.4 Light-sour sweet	3	6	3, 6, 10,
		2.5 Deep sweet	3	6	17, 32, 44,
		2.6 Sour	3	6	19, 33, 39
3.	Seed colour	3.1 Light yellow	19	38	1, 4, 8, 12, 13, 20, 21, 23, 24, 27, 31, 32, 33, 36, 38, 39, 44, 45, 47
		3.2 Light brown	12	24	3, 5, 6, 7, 11, 14, 15, 28, 29, 40, 43, 49
		3.3 Yellowish brown	9	18	2, 16, 18, 22, 25, 26, 34, 35, 46
		3.4 Dark brown	2	4	9, 50
		3.5 Blackish brown	8	16	10, 17, 19, 30, 37, 41, 42, 48

TABLE IV: LISTING OF QUALITATIVE DESCRIPTORS OF 50 MULBERRY GERMPLASM ON BASED OF FRUIT TRAITS

SI. No.	Acc. No.	Fruit colour	Fruit test	Seed colour
1.	BSRM-1	Cream	Sweet	Light yellow
2.	BSRM-2	Black- berry	Light sweet	Yellowish brown
3.	BSRM-3	Black	Light sour- sweet	Light brown
4.	BSRM-4	Black- berry	Sour- sweet	Light yellow
5.	BSRM-5	Cream	Light sweet	Light brown
6.	BSRM-6	Black- berry	Light sour- sweet	Light brown
7.	BSRM-7	White cream	Light sweet	Light brown
8.	BSRM-8	Reddish black	Sour- sweet	Light yellow
9.	BSRM-10	Black-berry	Sweet	Dark brown
10.	BSRM-11	Black-berry	Light sour sweet	Blackish brown
11.	BSRM-12	Black-berry	Sweet	Light brown
12.	BSRM-13	Reddish-black	Sour sweet	Light yellow
13.	BSRM-14	Pinkish	Light sweet	Light yellow
14.	BSRM-15	Black-berry	Sour- sweet	Light brown
15.	BSRM-16	Black-berry	Sour sweet	Light brown
16.	BSRM-18	Black	Sweet	Yellowish brown

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TABLE IV: LISTING OF QUALITATIVE DESCRIPTORS OF 50 MULBERRY GERMPLASM ON BASED OF FRUIT TRAITS

SI. No.	Acc. No.	Fruit colour	Fruit test	Seed colour
17.	BSRM-19	Pink	Deep sweet	Blackish brown.
18.	BSRM-20	Black-berry	Sour- sweet	Yellowish brown
19.	BSRM-21	Reddish black	Sour	Blackish brown
20.	BSRM-22	Reddish black	Sour- sweet	Light yellow
21.	BSRM-23	Black	Sweet	Light yellow
22.	BSRM-25	Cream	Light sweet	Yellowish brown
23.	BSRM-26	Reddish black	Sour- sweet	Light yellow
24.	BSRM-27	Black	Sweet	Light yellow
25.	BSRM-28	Pinkish	Light sweet	Yellowish brown
26.	BSRM-29	Orange	Light sweet	Yellowish brown
27.	BSRM-30	Cream	Light sweet	Light yellow
28.	BSRM-33	Cream	Sweet	Light brown
29.	BSRM-34	White cream	Sweet	Light brown
30.	BSRM-35	Pink	Sweet	Blakish brown
31.	BSRM-36	Black-berry	Sour- sweet	Light yellow
32.	BSRM-37	Pink	Deep sweet	Light yellow
33.	BSRM-38	Reddish black	Sour	Light yellow
34.	BSRM-40	Reddish black	Sour- sweet	Yellowish brown
35.	BSRM-42	Reddish black	Sour- sweet	Yellowish brown
36.	BSRM-45	Reddish black	Sour- sweet	Light yellow
37.	BSRM-46	White cream	Sweet	Blackish brown.
38.	BSRM-47	Reddish black	Sour- sweet	Light yellow
39.	BSRM-48	Reddish black	Sour	Light yellow
40.	BSRM-49	Pink	Sweet	Light brown
41.	BSRM-50	Orange	Sour-sweet	Blackish brown.
42.	BSRM-51	Cream	Sweet	Blackish brown.
43.	BSRM-53	Reddish black	Sour sweet	Light brown
44.	BSRM-54	Reddish Black	Deep sweet	Light yellow
45.	BSRM-55	Reddish black	Sour sweet	Light yellow
46.	BSRM-56	Black-berry	Sweet	Yellowish brown
47.	BSRM-58	Black	Sour sweet	Light yellow
48.	BSRM-59	White cream	Sweet	Blackish brown.
49.	BSRM-60	Reddish	Sweet	Light brown
50.	BSRM-61	Reddish black	Sour sweet	Dark brown

A. Quantitative Characters

The first approach towards the assessment of genetic diversity of any plant species is morphological investigation reported by [25]. The present study showed the morphological variations among the 50 mulberry genotypes belonging to 08 mulberry species (*Morus alba*, *Morus indica*, *Morus bombysis*, *Morus sinensis*, *Morus rubra*, *Morus laevigata* and *Morus nigra*). Range, men, standard deviation and CV% of the quantitative data of mulberry is presented (Table V).

TABLE V: DESCRIPTORS STATISTICS OF MULBERRY GERMPLASM BASED ON QUANTITATIVE TRAITS OF FRUITS DURING 2018-2020

SI. No.	Characters	Range		Mean	SD	CV (%)
		Max.	Min.			
1.	Fruit length (cm)	5.58	0.73	3.155	0.78	24.72
2.	Fruit width (cm)	1.9	0.52	1.21	0.34	28.10
3.	Single fruit weight (g)	4.11	0.07	2.09	0.82	39.23
4.	Fruit weight/plant (g)	2250.43	101.47	1175.95	448.75	38.16
5.	Seed setting (%)	94.24	8.13	51.19	20.16	39.42
6.	Sprouting (%)	96.67	36.67	66.67	14.85	22.27
7.	Rooting (%)	98.33	13.89	56.11	17.33	30.89
8.	Achene number/fruit	118.10	12.53	65.32	17.09	26.16
9.	Seed number/fruit	47.86	2.99	25.43	10.12	39.79
10.	100 seed weight (g)	0.166	0.019	0.0925	0.03	32.43

Among the studied genotypes, the seed number per fruit (CV-39.79%) was presented the highest quantitative variation which was followed by seed setting percentage (CV-39.42%), single fruit weight (CV-39.23%) and fruits weight per plant (38.16%). However, the fruit length ranged from 0.73 cm to 1.9 cm with an average 1.21 cm. The maximum longest fruit was found in BSRM-56 (5.58 cm), BSRM-1 (3.7 cm), BSRM-34 (3.4 cm), BSRM-22 (3.08 cm) and BSRM-21 respectively. The ranged of fruit width from 0.52 cm to 1.9 cm with an average 1.21 cm and achene number per fruit was 12.53 to 118.10 with an average 65.32. However, the maximum fruit width was observed in BSRM-56 (1.9 cm) followed by BSRM-1 (1.72cm) and BSRM-34 (1.7 cm) respectively. Single fruit weight was varied 0.07 to 4.11 g with an average 2.09 g. The maximum single fruit weight was in BSRM-56 (4.11 g) followed by BSRM-1 (3.43 g) and BSRM-34 (2.49 g) respectively. The ranged of fruit weight per plant was 101.47 to 2250.43 g with an average 1175.95 g. Furthermore, the maximum fruit weight per plant was found in germplasm BSRM-56 (2250.43 g) which was followed by BSRM-1 (1750.63 g) and BSRM-34 (1700.50 g), respectively, whereas minimum fruit weight per plant was in BSRM-48 (151.77 g). Similarly, a previous study was conducted by [8] on important fruit traits of 93 mulberry accessions and they found the wide range of variation among the fruit length, single fruit weight and fruit weight per plant.

They obtained the maximum fruit length, single fruit weight as well as fruit weight per plant was 4.2 cm, 3.3 g and 7261 g respectively. Furthermore, a previous study conducted on mulberry fruits indicated fruit length between 17.39 to 27.01 mm, fruit width 10.89 to 17.91 mm and single fruit weight per plant 1.38 to 3.77 g respectively among 13 mulberry genotypes sampled in the Mus province in the eastern Anatolia region of Turkey [26]. In mulberry breeding programs superior fruit weight is one of the most significant advantageous fruit characteristics [27] which was observed among the studied accessions. Rooting percentage ranged from 13.89 to 98.33% with an average 56.11%. Seed setting percentage ranged from 8.13 to 94.24% with an average 51.19% and sprouting% ranged from 36.67 to 96.67% with an average 66.6%. Similarly, [26] observed the great variation of sprouting percentage among the 10 mulberry genotypes where the sprouting percentage was above 95% in TRs, TR12 and S1708 mulberry varieties respectively. The maximum sprouting percentage was 98% in M5 variety followed by the TRs (97%) and S1708 (96%) varieties respectively. The maximum rooting percentage was in BSRM-10 (98.33%) followed by BSRM-8 (94.21%), BSRM-28 (93.98%), BSRM-15 (93.29%), BSRM-26 (92.26%) and BSRM-5 (90.48%) respectively. Achene number per fruit ranged from 12.53 to 118.10 with an average 65.32 and the maximum achene number per fruit was 118.10 in BSRM-56 followed by BSRM-1 (91.93) and BSRM-34 (60.23) respectively. The ranged of seed number per fruit was 2.99 to 47.86 with an average 25.43. The maximum seed number per plant was 47.86 in BSRM-56 followed by BSRM-1 (47.83) and BSRM-34 (46.97) respectively. Similarly, in a previous study was observed the great tend to the number of seed contained among the genotypes [28]. They showed that genotypes belonging to *M. bombysis* generally tended to have fewer seeds (<5 seeds), while *M. alba* genotypes contained 25 to 30 seeds per fruits and *M. latifolia* genotypes contained 15 to 35 seeds per fruits. Of these, several genotypes had >50 seeds per fruit - for example, Okarag-uwa had 80 seeds and Kanadasansou B had 53 seeds and they also found that genotypes, Oushuguwa and Memurasaki had no seeds which was correlated with our experimental findings. The weight of 100 seed was varied 0.019 to 0.166 g with an average 0.03 g. The maximum 100 seed weight was 0.166 g in BSRM-56 germplasm followed by BSRM-1 (0.164 g) and BSRM-34 (0.157 g) respectively (Table V). They also observed wide range of variation among the seed weight of various genotypes [29]. The ranged of seed weight was 0.6 mg (Isebudou genotype) to 68.2 mg (Okaraguwa genotype) which was lined with our findings. Likewise, in a previous study [15] observed the wide range variation for rooting%, seed setting%, achene number per fruit and 100 seed weight of mulberry genotypes. The individual data of each germplasm is shown (Table VI).

TABLE VI: QUANTITATIVE VARIATION OF FRUITS FOR DIFFERENT CHARACTERS OF MULBERRY GERMPLASM

SI. No.	Name of germplasm	Fruit length (cm)	Fruit width (cm)	Single Fruit weight (g)	Fruit weight/plant (g)	Sprouting (%)	Rooting (%)	Seed setting (%)	Achene number/fruit	Seed number/fruit	100 seed weight (g)
1.	BSRM-1	3.7	1.72	3.43	1750.63	75	57.45	85.66	91.93	47.83	0.164
2.	BSRM-2	1.33	0.87	0.42	1000.77	71.67	69.7	81.63	28.60	23.22	0.131
3.	BSRM-3	1.25	0.88	0.39	109.63	95	79.04	89.40	21.21	18.84	0.127
4.	BSRM-4	1.64	1.13	0.71	350.17	48.33	43.65	86.54	31.54	27.30	0.123
5.	BSRM-5	1.34	0.82	0.47	300.35	76.67	90.48	67.63	31.64	21.41	0.134
6.	BSRM-6	1.82	1.06	0.88	375.51	64.5	88.89	89.05	35.99	32.16	0.114
7.	BSRM-7	1.34	1.04	0.62	611.77	68.33	71.43	74.29	25.07	20.20	0.126
8.	BSRM-8	0.73	0.52	0.07	167.77	85	94.21	22.82	13.01	2.99	0.139
9.	BSRM-10	1.06	0.68	0.24	275.67	93.33	98.33	28.86	12.53	3.43	0.071
10.	BSRM-11	1.82	0.93	0.77	101.47	95	79.18	71.40	29.22	20.85	0.126
11.	BSRM-12	1.41	0.67	0.53	151.55	75	75.4	70.50	28.64	20.16	0.149
12.	BSRM-13	1.8	0.99	0.72	350.87	75	75.74	82.10	36.50	30.27	0.108
13.	BSRM-14	1.6	0.9	0.69	401.77	90	88.89	87.15	35.55	30.96	0.140
14.	BSRM-15	2	1.11	1.29	550.89	85	93.29	81.56	38.41	31.34	0.171
15.	BSRM-16	2.3	1.07	1.54	275.61	43	59.58	94.24	50.78	25.57	0.141
16.	BSRM-18	1.84	1.05	0.73	450.43	58.33	71.95	57.91	34.07	19.87	0.110
17.	BSRM-19	1.4	0.86	0.56	600.44	81.67	89.31	83.56	27.77	23.23	0.131
18.	BSRM-20	1.8	0.97	0.96	1001.86	61.67	67.5	91.29	35.36	32.35	0.136
19.	BSRM-21	2.83	1.4	2.45	1150.33	56.67	54.42	54.91	47.77	26.13	0.150
20.	BSRM-22	3.08	1.28	1.97	701.13	36.67	13.89	16.65	40.97	10.05	0.134
21.	BSRM-23	1.77	0.84	0.79	375.53	91.67	87.38	75.58	30.65	23.13	0.105
22.	BSRM-25	1.71	0.87	0.98	331.66	73.33	81.01	78.07	27.69	21.70	0.125
23.	BSRM-26	1.84	1.03	1.13	900.91	90	92.26	86.36	40.55	35.06	0.108
24.	BSRM-27	1.77	0.79	0.88	376.55	90	79.2	64.09	38.48	24.73	0.150
25.	BSRM-28	1.65	0.86	0.69	700.33	86.67	93.98	86.25	37.96	32.75	0.105
26.	BSRM-29	2.8	1.8	2.49	650.23	55	33.06	8.13	46.69	9.60	0.019
27.	BSRM-30	2.24	1.07	1.24	550.13	61.67	85.63	80.38	40.53	33.31	0.150
28.	BSRM-33	1.7	0.87	0.72	300.41	81.67	82.59	89.12	29.00	25.83	0.136
29.	BSRM-34	3.4	1.7	2.49	1700.55	75	87.67	80.48	60.23	46.97	0.157
30.	BSRM-35	1.36	0.71	0.32	150.77	86.67	72.71	78.02	20.28	15.81	0.091
31.	BSRM-36	1.93	0.92	0.91	475.23	56.67	65.28	58.14	44.95	26.13	0.110
32.	BSRM-37	1.36	0.93	0.35	450.31	79.67	55.79	73.41	24.38	18.00	0.142
33.	BSRM-38	1.79	0.99	0.83	350.47	96.67	57.96	70.92	31.23	22.20	0.147
34.	BSRM-40	1.93	1.14	1.05	750.27	70	63.89	85.98	37.75	32.57	0.116
35.	BSRM-42	2.13	1.14	1.12	800.53	50	64.37	93.22	47.59	44.34	0.147

TABLE VI: QUANTITATIVE VARIATION OF FRUITS FOR DIFFERENT CHARACTERS OF MULBERRY GERMPLASM

SI. No.	Name of germplasm	Fruit length (cm)	Fruit width (cm)	Single Fruit weight (g)	Fruit weight/plant (g)	Sprouting (%)	Rooting (%)	Seed setting (%)	Achene number/fruit	Seed number/fruit	100 seed weight (g)
36.	BSRM-45	2.39	1.07	1.3	1200.67	90	89.25	90.12	34.76	31.52	0.128
37.	BSRM-46	2.3	1.4	1.97	450.52	86.61	77.34	89.92	33.21	30.13	0.126
38.	BSRM-47	2	0.8	0.357	155.57	84.67	81.3	87.78	32.11	29.79	0.125
39.	BSRM-48	1.7	0.8	0.349	151.77	88.77	77.81	89.11	25.76	25.85	0.137
40.	BSRM-49	1.9	1.5	1.77	503.33	89.97	81.3	57.91	44.92	25.93	0.111
41.	BSRM-50	2.24	1.09	1.21	650.76	91.67	67.77	87.89	45.47	28.77	0.149
42.	BSRM-51	1.5	0.8	0.57	0.9	89.97	63.67	86.67	24.77	24.33	0.135
43.	BSRM-53	2	1.2	1.29	550.63	79.97	73.37	84.67	39.27	43.41	0.145
44.	BSRM-54	2.1	1.67	1.53	273.65	42.11	59.37	93.78	49.63	33.00	0.143
45.	BSRM-55	2.24	1.09	1.06	350.13	88.7	69.73	95.57	49.99	33.09	0.139
46.	BSRM-56	5.58	1.9	4.11	2250.43	77.87	87.61	91.67	118.10	47.86	0.166
47.	BSRM-57	2.7	1.8	2.39	201.29	75.63	59.8	89.97	45.79	24.37	0.148
48.	BSRM-59	1.9	1.5	1.463	800.33	86.67	79.79	88.99	44.93	33.57	0.146
49..	BSRM-60	2.21	1.09	1.31	751.19	88.71	83.31	93.79	49.33	46.77	0.145
50.	BSRM-61	1.9	1.3	1.316	902.41	91.1	83.67	88.96	42.32	33.67	0.147

However, several findings of our research are similar and some of the findings were disagreement with the above mentioned findings which might be due to the owed variability of used mulberry species or genotypes as well as edaphic and environmental factors that prevailing at the experimental site. Besides, it could be due to the comparatively larger fruit length and width the single fruit weight, fruit weight per plant, achene number per fruit, seed number per fruit and 100 seed weight were varied among the genotypes.

The identified leading traits were accounted by employed of PCA on the basis of higher fractions of overall variability to reduce the complexity among the experimental space and clearly visualize groupings, which was not possibly emerge from the raw data, [30]. However, the differentiations between genotypes were estimated on the PCA based correlation matrix and ten principal components, which explained 100% of the total difference (Table VII).

The result indicates that these charters had the maximum dissimilarity between the genotypes and also had the greatest impact on division of them [31]. 99.36% was accounted for first function which is largely inclined by seed setting and sprouting percentage. The second function was 0.306% of total variation which was mainly explained by acheine number per fruit, single fruit weight, and fruit width and fruit length respectively. In the same way, the third function was accounted for 0.185% of total variation that was commonly inclined by the traits of fruit production per plant, seed setting and sprouting percentage respectively. The fourth, fifth and six functions were accounted for 0.092%, 0.046% and 0.008% respectively. In case of fourth function 100 seed weight and rooting %, for fifth function fruit length, single fruit weight, seed setting%, fruit breath, fruit production per plant and rooting% as well as for six function all the traits except sprouting%, rooting% and achene number per fruit were mostly influenced. Furthermore, the seven, eight, nine and ten functions were accounted more than 100 percentage of total variation and the cumulative % of variation was 100 (Table VII).

TABLE VII: EIGENVALUES AND PROPORTION OF TOTAL VARIABILITY AND EIGENVECTORS OF TEN PRINCIPAL COMPONENTS (PCS) FOR STUDIED MULBERRY GENOTYPES

Variables	Components									
	1	2	3	4	5	6	7	8	9	10
Fruit length (cm)	-3.21E-04	1.63E-02	-1.45E-02	-2.62E-02	9.79E-03	4.82E-03	4.92E-01	8.46E-01	-1.99E-01	-3.15E-02
Fruit width (cm)	-1.91E-04	2.65E-05	-1.03E-02	-3.68E-03	2.94E-03	2.06E-02	2.88E-01	-3.76E-01	-8.80E-01	-2.79E-02
Single fruit weight (g)	-4.41E-04	3.59E-03	-1.75E-02	-1.95E-02	8.97E-03	6.18E-02	8.18E-01	-3.75E-01	4.29E-01	3.30E-02
Fruit production/plant (g)	-1.00E+00	-3.15E-03	8.75E-03	1.45E-03	2.62E-03	9.40E-04	-3.74E-04	5.64E-05	-6.79E-06	2.61E-06
Seed setting (%)	5.45E-03	-4.14E-01	3.42E-01	-5.04E-01	6.54E-01	1.69E-01	-2.08E-02	1.07E-03	-3.00E-03	5.97E-05
Sprouting (%)	1.66E-03	-5.13E-01	2.92E-01	-3.51E-01	-7.14E-01	-1.33E-01	1.95E-02	1.32E-03	-1.64E-03	-4.65E-04
Rooting (%)	-3.66E-03	-6.05E-01	-6.67E-01	1.34E-01	1.67E-01	-3.78E-01	1.46E-02	-2.70E-03	4.80E-03	4.23E-04
Achene number/fruit	-6.34E-03	4.24E-01	-4.03E-01	-7.66E-01	-4.51E-02	-2.59E-01	-2.16E-02	-2.32E-02	4.51E-03	1.17E-04
Seed number/fruit	-3.20E-03	-1.36E-01	-4.35E-01	-1.26E-01	-1.80E-01	8.60E-01	-6.15E-02	2.31E-02	-4.86E-03	2.53E-04
100 seed weight (g)	-5.27E-06	-4.24E-04	-3.89E-04	3.54E-04	2.96E-04	1.41E-03	3.45E-03	-2.86E-02	4.50E-02	-9.99E-01
Standard deviation	449.93	24.96	19.40	13.66	9.66	3.95	0.71	0.29	0.11	0.02
Percentage of variation	99.36	0.306	0.185	0.092	0.046	0.008	0	0	0	0
Cumulative %	99.36	99.67	99.855	99.946	99.992	100	100	100	100	100

In our study the significantly positive correlations were found among the studied characteristics of mulberry genotypes for simple correlation analysis (Table VIII).

From the correlation analysis, it is seen that the self-contribution of fruit length towards the achene number per fruit was highly positive which signifies that the attribute is remarkable responsive for direct selection towards the improvement of fruit in mulberry. Fruit width (FW) was observed to have a highly positive relationship with SFW and SNF respectively but strongly and negatively correlated with SS and SP. Seed setting% was highly positively correlated with SP and RP respectively. RP was found highly and positively related with SNF and SW but strongly and negatively related with FL and ANF. Highly positive association of SP and SS that indicates percentage of seed setting greatly influenced the sprouting percentage of mulberry. ANF and SNF exhibited highly positive association between fruit length and rooting% respectively. 100 seed weight was found positively correlated almost all the traits except fruit length and achene number per fruit.

However, in this study the fruit weight per plant was positively correlated with fruit length, fruit width, single fruit weight, achene number per fruit and seed number per fruit. These results were lined with previous findings of [32] in chestnut and [33; 10] in mulberry who, reported that length and width of the fruit were highly associated with fruit weight as well as fruit size and fruit weight were also significantly linked with each other.

TABLE VIII: CORRELATION STUDIED AMONG THE MEASURED VARIABLES IN MULBERRY GENOTYPES

Characters	Fruit length (cm)	Fruit width (cm)	Single fruit weight (g)	Fruit weight/ plant (g)	Seed setting (%)	Sprouting (%)	Rooting (%)	Achene number/fruit	Seed number/fruit	100 seed weight (g)
FL	1									
FW	0.516	1								
SFW	0.716	0.882	1							
FWP	0.188	0.248	0.246	1						
SS	-0.280	-0.178	-0.089	-0.157	1					
SP	-0.467	-0.211	-0.201	-0.045	0.629	1				
RP	-0.182	0.363	0.163	0.081	0.199	0.303	1			
ANF	0.809	0.378	0.482	0.167	-0.373	-0.459	-0.210	1		
SNF	0.219	0.600	0.483	0.142	-0.135	0.079	0.745	0.286	1	
SW	-0.234	0.337	0.243	0.094	0.106	0.110	0.523	-0.240	0.424	1

Here, FL = Fruit length, FW = Fruit Width, SFW = Single Fruit Weight, FWP = Fruit Weight per Plant, SS = Seed Setting Percentage, SP = Sprouting Percentage, RP = Rooting Percentage, ANF = Achene Number per Fruit, SNF = Seed Number per Fruit and SW = 100 Seed Weight.

IV. CONCLUSION

In our study, some morphological fruit characters of 50 mulberry genotypes grown in Bangladesh have been analyzed. To the best of our awareness, it is very limited research on this subject. However, the results indicate substantial variability among the studied germplasms. As a conclusion it can be said that the most divergent genotypes obtained in this study can be used in future mulberry crop improvement program.

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REFERENCES

[1] A. S. Hosseini, M. Akramian, A. Khadiviand H. S. Arjmand, "Phenotypic and Chemical Variation of Black Mulberry (*Morus nigra*) Genotypes",*Industrial Crops and Products*, vol. 117, pp. 260–271, 2018.

[2] Tikader and K. Vijayan, "Assessment of Biodiversity and Strategies for Conservation of Genetic Resources in Mulberry (*Morus* spp.)", *Bioremediation, Biodiversity and Bioavailability*, vol. 4, pp. 15–27, 2010.

[3] N. Gungor and M. Sengul, "Antioxidant Activity, Total Phenolic Content and Selected Physicochemical Properties of White Mulberry (*Morus alba* L.) Fruits", *International Journal of Food Properties*, vol. 11, pp. 44-52, 2008.

[4] S. Ercisli and E. Orhan, "Chemical Composition of White (Morus alba) Red (*Morus rubra*) and Black (Morus nigra) Mulberry Fruits", *Food Chemistry*, vol. 103, pp. 1380–1384, 2007, doi:10.1016/j.foodchem.2006.10.054.

[5] S. Kafkas, M. Ozgen, Y. Dogan, B. Ozcan, S. Ercisli and S. Serce,"Molecular Characterization of Mulberry Accessions in Turkey by AFLP Markers",*Journal of the American Society for Horticultural Science*, vol. 133, pp. 593-597, 2008.

[6] K. Vijayan, S. P. Chakraborti, S. Ercisli and P. D. Ghosh, "NaCI Induced Morpho-Biochemical and Anatomical Changes in Mulberry (*Morus* spp.)",*Plant Growth Regulation*, vol. 56, no. 1, pp. 61-69, 2008.

[7] Q. Yuan and L. Zhao, "The Mulberry (*Morus alba* L.) Fruit: A review of Characteristic Components and Health Benefits",*Journal of Agricultural and Food Chemistry*, vol. 65, pp. 10383-10394, 2017.

[8] H. Zhang, Z. F. Ma, X. Luo and X. Li, "Effects of Mulberry Fruit (*Morus alba* L.) Consumption on Health Outcomes: a Mini-review", *Antioxidants*, Basel. Switzerland, vol. 7, no. 5, pp. 69, 2018.

[9] S. Skrovankova, D. Sumczynski,J. Mlcek, T. Jurikovaand J. Sochor, "Bioactive Compounds and Antioxidant Activity in Different Types of Berries",*International Journal of Molecular Science*, vol. 16, no. 10, pp. 24673–24706, 2015.

[10] H. Krishna and A. Parashar, "Phytochemical Constituents and Antioxidant Activities of Some Indian Jujube (*Ziziphus mauritiana*Lamk.) Cultivars",*Journal of Food Biochemistry*, vol. 37, no. 5, pp. 571–577, 2013.

[11] Y. Jiang and W. J. Nie, "Chemical Properties in Fruits of Mulberry Species from the Xinjiang Province of China". *Food Chemistry*, vol. 174, pp. 460–466, 2015.

[12] M. Gundogdu, I. Canan, M. K. Gecer, T. Kan and S. Ercisli, "Phenolic Compounds, Bioactive Content and Antioxidant Capacity of the Fruits of Mulberry (*Morus* spp.) Germplasm in Turkey". *Folia Horticulturae*, vol. 29, no. 2, pp. 251–262, 2017.

[13] T. Mahmood, F. Anwar, N. Afzal, R. Kausar, S. Ilyas and M. Shoaib, "Influence of Ripening Stages and Drying Methods on Polyphenolic Content and Antioxidant Activities of Mulberry Fruits", *Journal of Food Measurement and Characterization*, vol. 11, no. 4, pp. 2171–2179, 2017.

[14] M. M. Natic, D. C. Dabic, A. Papetti, M. M. F. Akšic, V. Ognjanov, M. Ljubojevicand Z. L. Tešic, "Analysis and Characterisation of Phytochemicals in Mulberry (*Morus alba* L.) Fruits Grown in Vojvodina". *North Serbia. Food Chemistry*, vol. 171, pp. 128–136, 2015.

[15] M. S. Rahman, "Studies on genetic variability in mulberry (*Morus*spp)",*Ph.D. Thesis*, Rajshahi University, 2001.

[16] M. S. Lin, "Genetic Base of Japonica Rice Varieties Released in Taiwan", *Euphytica*, vol. 56, pp. 43-46, 1991.

[17] M. Elias, D. Mckey, O. Panaud, M. C. Anstettand T. Robert, "Traditional Management of cassava Morphological and Genetic Diversity by the Makushi Amerindians (Guyana, South America): Perspectives for On-farm Conservation of Crop Genetic Resources",*Euphytica*, vol. 120, pp. 57-143, 2001.

[18] A. M. Zacarias, A. M. Botha, M. T. Labuschagne and I. R. M. Benesi, "Characterization and Genetic Distance Analysis of Cassava (Manithol esculenta Crantz) Germplasm from Mozambique using RAPD Fingerprinting', *Euphytica*, vol. 138, pp. 49-53, 2004.

[19] E. Ertan, "Variability in leaf and fruit morphology and in fruit composition of chestnuts (*Castanea sativa* Mill.) in the Nazilli region

of Turkey", *Genetic Resources and Crop Evolution*, vol. 54, no. 4, pp. 691–699.2007.
[20] Annual Research Report of BSRTI, *Bangladesh Sericulture Research and Training Institute*, Rajshahivol. 25, no. 9, pp. 25-29, 2002.
[21] C. Hacketr, "A rapidly searchable Compendium of information on cultivated fruit, vegetable, spice and nutspecices",*ChronicaHorticulturae*, vol. 19, no. 2, pp. 31, 1979.
[22] CSRTI, "Mulberry Descriptor. Central Sericultural Research and Training Institute Central Silk Board", *Srirampuram*, India, 1986.
[23] H. Krishna, D. Singh, R. S. Singh, L. Kumar, B. D. Sharma, Saroj, Morphological and antioxidant characteristics of mulberry (*Morus* spp.) genotypes, *Journal of the Saudi Society of Agricultural Sciences*, vol. 19, no. 2, pp. 136-145, 2018.
[24] K. Vijayan, A. Tikader, Z. Weiguo, C. V. Nair, S. Ercisli and C. Tsou, "Wild Crop Relatives: Genomic and Breeding Resources, Tropical and Subtropical Fruits", *Springer-Verlag Berlin Heidelberg*, 2011, DOI. 10.1007/978-3-642-20447-0_5.
[25] M. Boubaya, Ben-Salah, N. Marzouguiand A. Ferchichi, "Pomological characterization of the mulberry tree (Morus spp.) in the South of Tunisia",*Journal of Arid Land Studies*, vol. 19, no. 1, pp. 157–159, 2009.
[26] Balik, M.K. Gecer and R. Aslantas, "Diversity of Biochemical Content in Fruits of Some Indigenous Mulberry Genotypes",*Turkish Journal of Agriculture and Forestry*, vol. 43, pp. 28-35, 2019.
[27] F. Aljaneand N. Sdiri, "Morphological Phytochemical and Antioxidant Characteristics of White (*Morus alba* L.), Red (*Morus rubra* L.) and Black (*Morus nigra* L.) Mulberry Fruits Grown in Arid Regions of Tunisia",*New Journal of Science, vol*. 35, no. 1, pp. 1940–1947. 2016.
[28] V. N. Y. Murthy, H. L. Ramesh, Munirajappa and B. R. D. Yadav, "Screening of Selected Mulberry (*Morus*) Germplasm Varieties through Propagation Parameters", *Journal of Natural Sciences Research*, vol. 2, no. 5, pp. 96-106,2012.
[29] H. Machii, A. Koyama and H. Yamanouchi, "Fruit traits of genetic mulberry resources", *Journal of Sericultural Science of Japan,*vol. 68, no. 2, pp. 145-155, 1999.
[30] A. D. Matteo, R. Russo, G. Graziani, A. Ritieni and C. D. Vaio, "Characterization of Autochthonous Sweet Cherry Cultivars (*Prunus avium* L.) of Southern Italy for Fruit Quality, Bioactive Compounds and Antioxidant Activity",*Journal of the Science of Food and Agriculture*, vol. 97, pp. 2782–2794, 2017.
[31] F. Iezzoni, M. P. Pritts and A. Kumar, "Applications of Principal Component Analysis to Horticultural Research", *HortScience*, vol. 26, pp. 334-338,1991.
[32] T. Marinoni, A. Akkak, C. Beltramo, P. Guaraldo, P. Boccacci,G. Bounous, A. M. Ferrara, A. Ebone, E. Viotto and R. Botta, "*Genetic and Morphological Characterization of Chestnut (Castanea sativa Mill.) Germplasm in Piedmont (north-western Italy)",Tree Genetics and Genomes*, vol. 9, pp. 1017–1030,2013.
[33] N. W. Peris, K. M. Gacheri, M. M. Theophillusand N. Lucas, "Morphological Characterization of Mulberry (Morusspp) Accessions Grown in Kenya",*Sustainable Agriculture Research*, vol. 3, no. 1, pp. 10, 2014.

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