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Phenotypic and chemical variation of black mulberry (*Morus nigra*) genotypes

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ABSTRACT

It is believed that black mulberry (*Morus nigra*) is a healthier fruit among mulberry species due to its high bioactive content. In the present study, the morphological and chemical variabilities of this species were investigated. There were statistical differences in terms of the morphological and chemical traits between the genotypes. Out of 37 morphological and seven chemical characters, 20 morphological and five chemical traits showed a coefficient of variation (CV) greater than 20.00%, indicating a high variability between the genotypes for these traits. The fruit weight varied between 1.79 and 5.69 g with an average of 3.85 g. The highest TSS content was 24.80%, while the lowest TSS was 11.20%, with an average of 18.42. The content of total anthocyanins was found between 57.62 and 475.65 mg CGE 100 g^{-1} FrWe. Total phenols ranged from 232.27 to 1777.73 mg GAE 100 g^{-1} FrWe. The fruit weight showed positive correlations with tree growth vigor, leaf length and leaf width. In addition, fruit weight was positively correlated with fruit length and fruit width. Furthermore, TSS was positively correlated with phenolic content and flavonoid content. The results obtained from the hierarchical grouping analysis separated genotypes into three and two main groups based on morphological and chemical characters, respectively. The present study increased knowledge about the phenotypic variation and phytochemical properties of black mulberry fruits and can be useful for producers, breeders, and processors.

1. Introduction

The mulberry (Urticales, Moraceae, *Morus* spp.), a perennial tree or shrub, is originated in temperate zones of Asia, and has now spread throughout the world (Benavides et al., 1994). *Morus* genus has three main species including white (*Morus alba*), red (*M. rubra*) and black (*M. nigra*) (Saadaoui and Albouchi, 2008). It is distributed mainly in the subtropical and temperate regions in the northern hemisphere. Mulberry is one of the oldest cultivated plants, due to the high morphological variability and the adaptability of the species to different and diverse harmful environmental conditions (Gray, 1990; Winn, 1996). Although the preservation of the genetic background of mulberry has been carried out mainly for the sericulture (Atmakuri et al., 2009), since the plants are used mainly for the leaves, the valorization of *Morus* spp. is essential for the development of human activities and subsistence in the poorest areas.

More recently, red and black mulberry fruits are highly consumed in different countries due to their high nutritional compounds and have gained an important position in the food industry due to the presence of anthocyanins (Ozgen et al., 2009) and other biologically active substances such as antioxidants, anti-mutagenic and anticancer (Atmakuri et al., 2009).

The nutritional potential and the great popularity of the mulberry fruits motivated the investigations on the chemical content and the antioxidant power of these fruits during the maturation to find new promising sources of natural antioxidants. The ripening of the fruit is usually accompanied by changes in fruit skin color due to changes in the pigments concentration of the superficial layers (Agati et al., 2005).

To improve the yield and number of leaves, it is important to characterize the germplasm and identify the various progenitors that can serve as potential allelic resources for the hybridization programs. The improvement is a continuous process, and it is a prerequisite to document all the variations found in the morphology in the initial stages of growth of tree improvement programs. A basic knowledge of the genetic architecture of the parent materials with respect to the traits that need improvement is a basic prerequisite. As is well known, the genetic improvement of all the fruit species depends on the genetic variation availability in the germplasm. Reliable information about

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Table 1
Descriptive statistics for morphological characters in the studied genotypes of black mulberry (*M. nigra*).

No.	Character	Abbreviation	Unit	Min	Max	Mean	SD	CV (%)
1	Tree growth habit	TrGrHa	Code	1	5	2.11	1.65	78.25
2	Tree growth vigor	TrGrVi	Code	1	5	3.88	1.25	32.29
3	Trunk diameter	TruDi	Code	1	5	3.00	1.61	53.70
4	Canopy density	CaDe	Code	1	5	2.55	1.22	47.92
5	Internode length	InLe	mm	19.51	63.96	36.97	8.56	23.15
6	Shoot branching	ShoBr	Code	1	5	3.80	1.30	34.21
7	Shoot density	ShoDe	Code	1	5	3.98	1.20	30.15
8	Current shoot color	CuShoCo	Code	1	3	1.38	0.78	56.81
9	Shoot flexibility	ShoFl	Code	1	5	2.95	1.27	43.12
10	Leaf density	LDe	Code	3	5	4.88	0.49	9.96
11	Leaf shape	LSh	Code	1	5	1.96	1.29	65.66
12	Leaf apex	LAp	Code	1	3	2.57	0.82	32.06
13	Leaf serration type	LSeTy	Code	1	1	1.00	0.00	0.00
14	Leaf serration number	LSeNo	Number	22	51	31.04	4.73	15.23
15	Leaf upper surface color	LUpSuCo	Code	1	1	1.00	0.00	0.00
16	Leaf lower surface color	LLoSuCo	Code	1	1	1.00	0.00	0.00
17	Leaf pubescence	LPu	Code	0	0	0.00	0.00	0.00
18	Leaf lobe presence	LLoBP	Code	0	0	0.00	0.00	0.00
19	Leaf length	LLe	mm	96.62	186.13	143.97	14.10	9.79
20	Leaf width	LWi	mm	75.14	147.66	117.42	11.76	10.02
21	Petiole length	PeLe	mm	19.12	38.68	30.21	3.67	12.15
22	Petiole diameter	PeDi	mm	1.90	3.88	3.04	0.39	12.79
23	Ripening time	RiTi	Code	1	1	1.00	0.00	0.00
24	Fruit density	FrDe	Code	1	5	3.73	1.47	39.41
25	Fruit length	FrLe	mm	18.29	30.23	24.51	2.45	9.99
26	Fruit width	FrWi	mm	14.49	22.24	18.13	1.29	7.12
27	Fruit weight	FrWe	g	1.79	5.69	3.85	0.81	21.13
28	Fruit stalk length	FrStLe	mm	0.97	4.18	2.32	0.69	29.70
29	Fruit stalk diameter	FrStDi	mm	1.03	1.70	1.42	0.15	10.30
30	Fruit stalk color	FrStCo	Code	1	1	1.00	0.00	0.00
31	Fruit color	FrCo	Code	1	3	1.55	0.90	58.00
32	Fruit shape	FrSh	Code	1	3	2.57	0.82	32.06
33	Fruit taste	FrTa	Code	1	5	3.09	0.87	27.99
34	Fruit drupelet density	FrDrDe	Code	1	5	4.04	1.23	30.45
35	Fruit pubescence	FrPu	Code	0	1	0.36	0.48	133.61
36	Fruit juice content	FrJuC	Code	1	5	3.12	1.30	41.51
37	Seed presence	SePr	Code	1	1	1.00	0.00	0.00

genetic identity and the relationship between genotypes is necessary to develop and maintain a diverse germplasm. The characterization of germplasm is essential to identify individual genotypes and also to measure the degree of variability between the accessions (Ozgen et al., 2009).

The selection of the appropriate genotypes requires a thorough knowledge of the morphological characters and the phytochemical composition of fruits in the different species of mulberry. The morphological and phytochemical analyses are important for the identification of the stock in mulberry. Mulberry breeding aims to continue identifying and creating genetic variability, assembling economic traits in productive genotypes and matching genotypes with the appropriate environment. In Iran, black mulberry fruits are processed to obtain special traditional products, which offer a good help in the consumption of food; however, the biochemical and nutritional composition of neglected, used and marketed cultivars is poorly understood (Giuliani et al., 2011).

Understanding the phenotypic and chemical variation of black mulberry as a valuable fruit, is necessary. There has been no report on the morphological and chemical characterization of mulberry germplasm collections in Iran so far. Therefore, the objective of the present study was to evaluate the state of biodiversity in the spectrum of black mulberries distributed in the Markazi province using the main morphological and biochemical characteristics. In addition, with the objective of a better characterization of this genetic set, potentially useful in breeding and production, some important qualitative features of the fruits were regraded.

2. Materials and methods

2.1. Plant material

In the present study, a total of 112 mulberry genotypes representing *M. nigra* species were investigated. The plant materials were obtained from several regions of the Markazi province in Iran including Jazanagh (J), Ghaleno (Gh), Sanavor (S), Enaj (En), Karkan (K), Javersian (Ja), Escon (E), Gavgodar (Ga), Arak (Ar), Ghaledeshirkan (Gha), Masolia (M), Manizan (Ma), Chara (C), Far (F), Anjedan (A), Amanabad (Am) and Barzok (B). As the Markazi province is far from the sea and has great height, it has a long winter. Its condition is very cold and snowy during the winter, while, its climate is cool in the highlands and warm in the lowlands during the summer. Mulberry trees in Iran have been generally found in natural cultivation areas and similar genotypes are not presented.

Fruits and leaves were collected for analyses from different branches per tree in the area of natural growth. The fruits were taken during the mature commercial stage and then transported to a laboratory for analysis. The samples were divided into two sections, and the first section consisted of 40 fruits which were used for morphological measurements. The second section contained 40 fruits which were kept at −20 °C until the chemical studies.

2.2. Morphological evaluation

The morphological characteristics were performed according to the mulberry descriptor provided by the Central Research and Training Institute (CSRTI, 1986). In total, 37 phenotypic traits including 26