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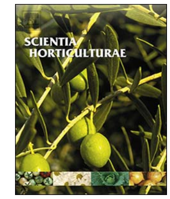

Phenotypic characterization of black raspberry to select the promising genotypes

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A B S T R A C T

Black raspberry is a valuable fruit crop that is cultivated in many parts of the world and its fruit is directly used in agriculture, and indirectly in the food and confectionery industry. In the current study, the phenotypic and biochemical variations of black raspberry genotypes were studied with the aim of introducing superior genotypes. Significant differences were observed among the genotypes for most of the studied traits. The flowering date varied from April 28 to June 09, and the fruit ripening time was from May 26 to August 05. The highest fruit weight was 5.67 g and the lowest fruit weight was 0.43 g which showed high variation (CV = 92.94%). Total soluble solids (TSS) ranged from 4.00 to 28.00%, while the total anthocyanin varied from 79.62 to 898.40 mg/100 g fresh fruit weight. Fruit weight showed positive and significant correlations with fruit length (r = 0.93), fruit width (r = 0.86), drupelet strength (r = 0.42) and fruit shape (r = 0.39). TSS showed positive and significant correlations with the ripening date (r = 0.34) and anthocyanin content (r = 0.32), which confirms that sugar is the main contributor to anthocyanin synthesis. The principal component analysis (PCA) showed that the 10 components explained 80.12% of the total variance. Hierarchical cluster analysis grouped the genotypes into two main clusters with four sub-clusters. While the many genotypes showed potential, 18 genotypes were superior in terms of the fruit quality and can be singled out for cultivation and also are valuable gene pools for breeding programs.

1. Introduction

Raspberries (*Rubus* genus, the family Rosaceae) are originated from the Northern hemisphere (Anonymous, 2010). Two species of raspberries are valuable horticulturally, including red raspberries (*R. idaeus* L.) and black raspberries (*R. occidentalis* L.). One of the key problems with the production of this fruit is the lack of cultivars with high fruit quality for processing, high yield, and resistance to disease and pests. The qualitative traits of fruit are size, firmness, color, taste, texture and overall appearance. Maintaining a desirable flavor with acceptable color and flesh texture, while increasing fruit size, yield, and postharvest storage capacity is essential. Although some of these traits can be incorporated into new cultivars using a conventional breeding approach, the process is time consuming and unstable (Umar et al., 2010).

Black raspberries are suitable for areas with a well-defined winter (Moore, 1984). In addition, the plant is a specialty for temperate regions, which is a suitable option for small producers due to the low cost of developing and maintaining orchards with fast and high economic performance (Antunes et al., 2000). In black raspberry fruit, vitamin C, phenolic compounds and natural pigments such as anthocyanins are generally high. These attributes have led to the use of black raspberries for the production of products such as gelatin, yogurt, sweets and water, high nitrogenous properties, in addition to selling fruits as fresh fruit and frozen dough (Hussain et al., 2014; Antunes et al., 2014). Anthocyanins are attractive colors used in the food industry (Tiwari et al., 2009; Acosta-Montoya et al., 2010; Ali et al., 2011). Levels of anthocyanins and total phenolics in black raspberry fruits have been found to compare favorably to a variety of other small fruits such as elderberries, huckleberries, blueberries, and black currants. Black raspberries and other sources of dietary anthocyanins have been linked to many possible health benefits such as reducing eyestrain, improving night vision, helping to prevent macular degeneration, anti-inflammatory effects, protecting against DNA damage, and exhibiting anti-cancer activity (Rezaee-Kivi and Sartipnia, 2013). Studies linking the high anthocyanin value of black raspberry with potential health benefits have led to increasing interest in this fruit, from various functional food and nutraceutical markets.

Awareness of genetic diversity patterns in wild relatives of domestic and commercial species can be used to improve the genetic properties of new cultivars. Wild relatives usually have traits, gene alleles, and

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Table 1
Descriptive statistics for the measured characters in the studied genotypes of black raspberry.

No.	Character	Abbreviation	Unit	Min	Max	Mean	SD	CV (%)
1	Flowering date	FD	Date	28-Apr	09-Jun	09-May	1.95	36.42
2	Petal color	PC	Code	1	7	5.62	2.22	39.41
3	Petal number	PN	Number	5	5	5.00	0.00	0.00
4	Petal length	PLe	mm	5.44	17.79	9.32	2.65	28.42
5	Petal width	PW	mm	3.15	12.85	6.59	1.89	28.62
6	Shrub growth habit	ShrGH	Code	1	3	2.86	0.51	17.94
7	Leaf length	LLe	mm	25.81	132.54	60.29	21.22	35.19
8	Leaf width	LW	mm	17.16	89.24	43.75	17.58	40.18
9	Leaf color	LC	Code	1	5	3.60	1.52	42.17
10	Leaflet petiole length	LtPeLe	mm	0.00	27.78	4.68	4.73	101.00
11	Leaf shape	LS	Code	1	5	2.94	1.81	61.50
12	Leaf serration type	LSeT	Code	1	1	1.00	0.00	0.00
13	Terminal leaflet length	TeLtLe	mm	20.87	138.82	67.10	22.64	33.74
14	Terminal leaflet width	TeLtW	mm	18.07	77.05	47.56	13.71	28.83
15	Terminal leaflet depth	TeLeDe	Code	1	5	3.90	1.43	36.72
16	Young shoot color	YShC	Code	1	7	2.45	1.83	74.49
17	Young shoot shape	YShS	Code	1	3	1.62	0.93	57.41
18	Young shoot pubescence	YShPu	Code	1	1	1.00	0.00	0.00
19	Young shoot spine presence	YShSpPr	Code	0	1	0.92	0.27	29.67
20	Young shoot spine number	YShSpN	Number	0	120	31.54	26.41	83.73
21	Spine length	SpLe	mm	0.00	33.00	5.13	3.80	74.02
22	Annual shoot color	AShC	Code	1	7	5.56	1.95	35.07
23	Annual shoot diameter	AShDi	mm	3.33	10.75	6.26	1.80	28.75
24	Spine presence on shrub	SpPrShr	Code	0	5	1.60	1.25	77.94
25	Ripening date	RD	Date	26-May	05-Aug	09-Jul	1.78	41.61
26	Bunch length	BunLe	mm	45.92	451.28	182.95	83.86	45.84
27	Bunch width	BunW	mm	26.83	215.29	76.37	35.24	46.15
28	Fruit number on bunch	FrNBun	Number	4	167	47.95	38.80	80.92
29	Drupelet strength	DrSt	Code	1	5	3.56	1.24	34.89
30	Fruit shape	FrS	Code	1	7	3.20	2.67	83.56
31	Fruit color	FrC	Code	1	1	1.00	0.00	0.00
32	Seed length	SeLe	mm	1.31	4.66	3.28	0.75	22.71
33	Seed width	SeW	mm	0.41	3.51	2.13	0.65	30.33
34	Fruit weight	FrWe	g	0.43	5.67	1.43	1.33	92.94
35	Fruit length	FrLe	mm	8.71	25.75	13.87	4.47	32.24
36	Fruit width	FrW	mm	9.74	22.33	13.87	2.80	20.20
37	Total soluble solids	TSS	%	4.00	28.00	12.86	5.41	42.08
38	Anthocyanin	Ant	mg/100 g FreFrWe	79.62	898.40	355.53	154.31	43.40
39	Titratable Acidity	TA	%	0.50	1.02	0.76	0.14	18.29
40	TSS/TA	TSS/TA	Ratio	5.00	36.00	17.17	6.81	39.67

unique genetic structures that are not found in domesticated representatives of these species. The domestication process is usually accompanied by the reduction or elimination of genetic diversity due to predetermined breeding objectives and a limited number of genotypes used in breeding programs. In this way, the cultivated forms are more homogeneous than wild ones (Singh, 2001). Therefore, preservation and study of natural germplasm are important as a potential genetic donor for the conservation and utilization of plant genetic resources.

The study of genetic variation of plants is one of the innovation activities related to food and agricultural research, such as breeding and improvement programs (Govindaraj et al., 2015). However, information on the extent and pattern of genetic diversity is essential for the proper use of plant genetic resources (Hegde et al., 2000). This can be achieved by collecting, protecting and characterizing germplasm using morphological, phytochemical and molecular methods (Kresovich and McFerson, 1992). The best strategy in breeding programs is the use of local germplasm and commercial cultivars to produce high quality and consistent cultivars for each region (Clark and Finn, 2011). Identification using morphological characters is a quick, intuitive, and easily identifiable way. It is very suitable for breeders and nurserymen to identify an unknown variety for its prevention.

The diversity of genetic resources of *Rubus* species is very high in Iran (Rechinger, 2001, 2003; Khatamsaz, 1992). *Rubus sanctus* Schreb. (syn. *R. anatolicus* (Focke) Hausskn.) is the most common species in Iran (Khatamsaz, 1992) and is widely distributed from the wet climate in the north of Iran (Caspian Sea area) to the cold climate in the west and even to some semi-arid and hot climates in the south-west of the country. But some species like *R. hirtus* Waldst. and Kit., *R. hyrcanus* Juz. and *R. persicus* Boiss and some interspecific hybrids have limited distribution just in some parts of humid and sub-humid climatic condition of the north of Iran (Caspian Sea area). Caspian Sea area is located between the Caspian Sea and Alborz mountain chains in the north of Iran including Mazandaran and Gilan Provinces. This region has humid climatic conditions and is one of the most important regions of speciation of *Rubus* species. Almost all of the *Rubus* species and inter-specific hybrids are present in this region.

So far, raspberry cultivation in Iran has not been carried out, and there are no commercial black raspberries in Iran, although collecting and supplying wild black raspberries is common in the country. Therefore, there is no comprehensive study that can provide a full understanding of the nutritional value of the genetic resources available in this valuable crop in Iran. Thus, the present study was conducted with the aim of determining the phenotypic and biochemical diversity of black raspberry genotypes in Babul area with climatic conditions in the Caspian Sea area from the north of Iran. In addition, evaluation of economically valuable characteristics was conducted to identify the genotypes with a suitable potential for cultivation or exploitation in breeding programs.

2. Materials and methods

2.1. Plant material

In the current study, 100 black raspberry genotypes were evaluated from five natural habitats in Babul area of Mazandaran province in the