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WATER-SOLUBLE ANTIOXIDANT POTENTIAL OF MELON LINES GROWN IN TURKEY

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The antioxidant potential of 42 melon* (Cucumis melo) *lines including six cultivars grown in Turkey was assessed by measuring total water-soluble antioxidant capacity, phenolic and vitamin C contents. The lines showed significant variability for all three antioxidant parameters with breeding lines having higher antioxidant capacity and phenolic content than some popular cultivars. Different types of melons also showed significantly different antioxidant potentials. Thus, galia and ananas types showed a higher mean antioxidant capacity and phenolic content than the other tested types (yuva, kislik, canary, and charentais). Correlation analysis between antioxidant parameters showed a significant correlation between water-soluble antioxidant capacity and phenolic content.

Keywords: Cucumis melo*, Antioxidant capacity, Phenolics, Vitamin C, Horticultural traits.*

INTRODUCTION

Reactive oxygen species (ROS) are highly reactive oxidants that are formed in living organisms as a result of metabolic processes and exposure to external factors like industrial solvents, UV, and other types of radiation.[1,2] ROS and other free radicals cause damage to DNA, proteins, and lipids, which may give rise to serious degenerative diseases, such as cancer, artherosclerosis, neurological diseases, heart disease, immunodeficiencies, type II diabetes, and stroke.[1] Antioxidants are important guardians of the cell's building block molecules. Antioxidants interact with free radicals and stabilize them by donating hydrogen atoms or electrons. Thus, antioxidants prevent ROS from oxidizing and harming biomolecules.[3] Antioxidant molecules have different physicochemical features and can be separated into two classes: water soluble and lipid soluble antioxidants. Ascorbic acid (vitamin C) is a water soluble antioxidant that acts as an electron donor and donates hydrogen to lipid radicals. Phenolic compounds are a dominant group of water soluble antioxidants, which are primarily substituted benzoic and cinnamic acid compounds that give flavor to fruits and vegetables.[4] Tocopherols, carotenoids, and lycopene are lipid

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soluble antioxidants that are especially important ROS scavengers in the lipophilic compartments of the body. Previous studies showed that water-soluble antioxidants dominate lipid-soluble antioxidants in fruits and vegetables.[5,6] For example, in strawberries, the lipophilic antioxidant capacity is only 0.83% of total antioxidant capacity.[6] Although antioxidant molecules are necessary for good health, the human body cannot synthesize most common antioxidants. Instead, these beneficial molecules (i.e., antioxidant) are obtained via consumption of fruits and vegetables. It has been reported that consumption of fruits and vegetables decreases the risk of many diseases that are known to result from free radical damage.[7,8] Although it has been hypothesized that antioxidants in dietary plants protect against oxidative stress-related diseases, the results of research on single compounds (such as vitamins E and C or β-carotene) when used as supplements suggest that these compounds have little or no protective effects against such diseases.[9–11] In other work, it has been demonstrated that the antioxidant compounds in fruits and vegetables have synergistic effects and work better in combination.[12] Thus, intake of antioxidant compounds via the diet is much more beneficial than their use as dietary supplements.

Melon (*Cucumis melo*) is a member of the *Cucurbitaceae* family, which also includes cucumber, squash, and pumpkin. Melon has significant commercial value and is grown by farmers throughout the world. According to the FAO (Food and Agriculture Organization), approximately 26 million metric tons of melon were produced in the world in 2007 with Turkey ranking second (1.37 million metric ton) after China.[13] Melons are classified according to their shape, color, and other fruit characteristics, and many types are grown all over the world (e.g., cantaloupe, muskmelon, honeydew, galia) while others are regional.[14] The types of melons used in this study were: galia, ananas, kirkagac, canary, charentais, yuva, and kislik. Galia type melons (*C. melo* var. *reticulatus*) originated in Israel and are grown in early summer. These melons are similar to cantaloupe but are larger and with pale green flesh.[14] Ananas type melons (*C. melo* var. *reticulatus*) have large oval fruits with a pineapple scent and orange-yellow skin with netting.[14] Kirkagac melons (*C. melo* var. *inodorus*) have yellow skin flecked with dark green spots and yellowish flesh. Kirkagac melons are of Turkish origin and are named after a town in the western part of the country. Canary type melons (*C. melo* var. *inodorus*) are large and bright yellow with white or pale green flesh.[14] Charentais melons (*C. melo* var. *cantalupensis*) originated in France and have gray skin and orange flesh.[14] Yuva melons (*C. melo* var. *inodorus*) have dark green skin with pale green to white flesh. Kislik (winter) type melons (*C. melo* var. *inodorus*) are yellow melons that are grown late in the season and have a long storage life. In addition to being an important producer of melon, Turkey is a secondary center of diversification and domestication for the crop, and some cultivars, including kirkagaç, yuva, and kislik, are specific to and widely grown in Turkey. Melon is mainly used as a fresh fruit but can also be cooked and candied. In some parts of the world, immature fruits are eaten as a vegetable and the roots are used for medicine.[15] Melon consists of approximately 90% water and is a good source of fiber. It also contains a high amount of carbohydrates and phytochemicals, including antioxidants and minerals.[16] In recent work, a few melon cultivars have been tested for total antioxidant, phenolic, and vitamin C contents.[17–19] However, to our knowledge there is no comprehensive study comparing water-soluble antioxidant activity and total phenolic and vitamin C contents in different melon cultivars and breeding lines.

The goal of this study was to determine the total water-soluble antioxidant capacity and total phenolic and vitamin C contents of 42 melon lines grown in Turkey. Lipid soluble antioxidant capacity was not determined because it has been demonstrated

to constitute a very small portion of total antioxidant content in melon.[20] We also examined the relationship between the antioxidant parameters and several horticultural traits. Identification of melon lines with high water-soluble antioxidant activity and antioxidant compound contents will be useful for plant breeders to map the loci that control these traits and for breeding of new cultivars with elevated levels of antioxidants, which are beneficial for human health.

MATERIALS AND METHODS

Plant Material

Seeds for the melon lines were obtained from Yüksel Seed Ltd., Antalya, Turkey. All named cultivars are commercially available; seeds for these cultivars and information about the availability of breeding lines may be obtained from Yüksel Seed Ltd. (http://yukseltohum.com/site/). Seeds were sown in a climate-controlled greenhouse in Antalya on March 22, 2008. Seedlings were transplanted to a nethouse –type greenhouse on April 24 with 12 plants grown for each melon line. Plant rows were 90 cm apart with 50 cm between each plant in a row, thereby giving a planting density of 2.2 plants per square meter. Melons were harvested in June at the normal market stage, which was assessed based on fruit color, texture, and softness at the blossom end. Melon flesh was cut into cubes and samples were stored at −20°C until assays were performed. All assays were completed within 1 month of harvest with two separate extracts prepared from each line and replicate measurements made from each extract as described in the following sections.

Total Water-Soluble Antioxidant Capacity

For the determination of total water soluble antioxidant capacity, a 100-g sample was homogenized with 200 mL of cold distilled water for 2 min at low speed in a Waring blender (Model HGB2WTS3; Waring Corp., Torrington, CT, USA) equipped with a 1-L double-walled stainless steel jar chilled by circulating water at 4°C. Then 15 mL of cold distilled water was added to 10 mL of extract. This mixture was homogenized for 1 min and filtered through four layers of nylon cloth. The filtrate was further claried by centrifugation at 3000 g for 10 min at 4°C. The clear supernatant was again filtered through four layers of nylon cloth and used for the determination of antioxidant capacity according to the method of Re et al. (1999).[21] This method measures the decolorization of ABTS [2,2#-azinobis-(3-ethyl-benzothiazoline-6-sulfonic acid)] radical cation caused by the test sample. Decolorization was monitored by spectrophotometer (Model 1700; Shimadzu, Kyoto, Japan) at 734 nm. Each reaction mixture contained 2 mL of ABTS radical solution in phosphate-buffered saline at pH 7.4 (previously oxidized by potassium persulfate) and 2.5, 5, or 7.5 μL of melon extract. For the standard curve, 20 μL Trolox (0.0045–0.03 mmol in reaction mixture) was used in place of the melon sample. The reduction in sample absorbance was monitored for 6 min and the analysis was repeated three times for each sample volume and for each melon extract with two extracts prepared for each melon line. Percent of absorbance decrease (percent inhibition) at 1, 3, and 6 min was plotted against sample volume. The slope for each graph was determined and graphed against time using KaleidaGraph (Synergy Software, Reading, PA, USA). Then areas under curve (AUC) values were calculated using the same software. The trolox standard curve and AUC

values for each melon sample were then used to calculate total water soluble antioxidant capacity expressed as μmol Trolox equivalents (TE)· kg^{-1} fresh weight (FW).

Total Phenolic Content

For total phenolic content determination, homogenization was the same as for measurement of antioxidant capacity and the method of Singleton and Rossi was used.[22] Folin-Ciocalteu was used as the reactive reagent and gallic acid was used as the standard. For each sample, 2 mL of melon extract was mixed with 10 mL 2 N (10%) Folin-Ciocalteu's reagent. After 3 min, 8 mL 0.7 M sodium carbonate was added and the reaction mixture was incubated for 2 h at room temperature. Absorbance was then measured at 765 nm in a spectrophotometer. For each sample, this analysis was carried out three times. Total phenolic content in the samples was expressed as milligrams gallic acid equivalents/kg^{-1} FW of melon.

Vitamin C Content

For vitamin C content determination, the AOAC 967.21 titrimetric method was used.[23] In this method 2,6-dichloroindophenol was used as the reactive substance and L-(+)-ascorbic acid was used for calibration. Extractions were carried out by homogenization of 100 g of melon with 115 mL of acetic acid–metaphosphoric acid extraction solution for 2 min at low speed in a Waring blender at 4°C. A 35-g sample of each homogenate was diluted with extraction solution to a nal volume of 100 mL, filtered through nylon cloth and then used in titration. For each melon line, two extracts were prepared and three replicates of the vitamin C assay were performed with each extract. Vitamin C content in melon samples was calculated as milligrams vitamin C/kg^{-1} FW of melon.

Horticultural Traits

Each melon line was assessed for several horticultural parameters as shown in Table 1. In order to do correlation analysis, melon traits (except fruit weight) were converted to numeric scales. Fruit weight was estimated in kilograms and fruit shape was scored as 1 for round fruit, 2 for oval fruit, and 3 for oblong fruit. Plant vigor was also assessed using a three-point scale: 1 = weak growth, 2 = moderately strong growth, 3 = strong, healthy growth. Earliness was assessed using a scale of 1 to 3 with early and late lines receiving scores of 1 and 3, respectively. Fruit shelf life was measured by assessing melons for softness 7, 14, and 21 days after harvest. For this assessment, fruit was kept at room temperature and was hand-tested for softness at one week intervals. Fruit that softened beyond an acceptable level after 7 days were scored as 1 while fruit that only softened significantly after 21 days, was scored as 3. Flesh color was also determined but not used in correlation analysis because no suitable numeric conversion was feasible.

Statistical Analyses

Total water-soluble antioxidant capacity, total phenolic content, vitamin C content, and phenotypic traits of the melons were analyzed using analysis of variance and Fisher's protected least signicant difference as implemented by StatView software (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

In this work, 42 melon lines including 15 cultivars were tested for total water soluble antioxidant capacity, total phenolic content, and vitamin C content. Most of the lines were bred in Turkey (36) while six were non-Turkish melon cultivars that are widely grown in Turkey. The melon classes with the most representatives were galia, ananas, and kirkagac types with 14, 15, and 7 lines, respectively (Table 1).

Table 1 Description and horticultural parameters for melon lines assayed for water-soluble antioxidants.

Cultivar	Type	Country of origin	Fruit weight (kg)	Fruit shape	Plant vigor	Earliness	Shelf Life
Balhan	Galia	Turkey	2	Oval	Moderate	Early	Long
Citirex	Galia	France	2	Round	Strong	Early	Moderate
Fiat	Charentais	Turkey	2	Round	Moderate	Early	Moderate
GV-42001	Canary	France	1	Round	Moderate	Early	Moderate
Hisar	Kirkagac	Turkey	4	Round	Strong	Late	Long
Kirkagac-85	Kirkagac	Turkey	3	Round	Strong	Normal	Long
Kirkagac-86	Kirkagac	Turkey	3	Oval	Strong	Late	Long
Lavi	Galia	Israel	4	Oval	Strong	Normal	Moderate
Medetli	Ananas	Turkey	3	Oval	Strong	Late	Long
Moncayo	Canary	Netherlands	1	Round	Moderate	Early	Moderate
Sally	Galia	USA	3	Round	Strong	Normal	Moderate
Sarıca	Ananas	Turkey	2	Round	Moderate	Early	Moderate
seyran	Galia	Turkey	2	Round	Moderate	Early	Moderate
Sinem	Kirkagac	Turkey	3	Oval	Moderate	Early	Moderate
Yakupbey	Yuva	Netherlands	4	Oval	Strong	Late	Long
BL-1	Kislik	Turkey	2	Oval	Moderate	Early	Short
BL-2	Galia	Turkey	5	Oblong	Strong	Early	Moderate
BL-3	Galia	Turkey	3	Oval	Moderate	Early	Moderate
BL-4	Galia	Turkey	3	Oblong	Moderate	Early	Moderate
BL-5	Galia	Turkey	3	Oval	Strong	Normal	Long
BL-6	Galia	Turkey	3	Oval	Moderate	Early	Moderate
BL-7	Ananas	Turkey	3	Oval	Moderate	Early	Moderate
BL-8	Ananas	Turkey	3	Oval	Strong	Normal	Long
BL-9	Kirkagac	Turkey	3	Oval	Strong	Late	Long
BL-10	Kirkagac	Turkey	2	Oval	Strong	Late	Long
BL-11	Galia	Turkey	2	Oval	Moderate	Early	Moderate
BL-12	Ananas	Turkey	3	Oval	Strong	Normal	Moderate
BL-13	Ananas	Turkey	4	Oval	Moderate	Early	Moderate
BL-14	Ananas	Turkey	2	Oval	Moderate	Early	Moderate
BL-15	Ananas	Turkey	3	Oval	Strong	Early	Moderate
BL-16	Ananas	Turkey	3	Oval	Strong	Normal	Moderate
BL-17	Ananas	Turkey	2	Oval	Strong	Early	Moderate
BL-18	Galia	Turkey	2	Oval	Strong	Early	Moderate
BL-19	Galia	Turkey	6	Oblong	Strong	Late	Long
BL-20	Ananas	Turkey	4	Oval	Strong	Late	Long
BL-21	Ananas	Turkey	3	Oval	Strong	Late	Long
BL-22	Ananas	Turkey	3	Oval	Strong	Late	Long
BL-23	Kislik	Turkey	3	Round	Strong	Late	Long
BL-24	Kirkagac	Turkey	2	Round	Weak	Normal	Short
BL-25	Ananas	Turkey	3	Oval	Strong	Early	Moderate
BL-26	Galia	Turkey	3	Oval	Strong	Late	Long
BL-27	Ananas	Turkey	3	Oval	Strong	Normal	Moderate

Total Water-Soluble Antioxidant Capacity

Among the melon lines, significant variation was observed for total water soluble antioxidant capacity. Total water soluble antioxidant capacity fluctuated between 1.18 mmol TE kg^{-1} for BL-1, a kislik type, to 4.64 mmol TE·kg^{-1} for BL-3, a galia type melon (Table 2). Thus, a nearly 4-fold difference was observed between the lines

Table 2 Antioxidant contents of the melon lines.[z]

Line	Antioxidant activity (μmol TE·kg^{-1}) ± SE	Rank	Phenolics content (mg·kg^{-1}) ± SE	Rank	Vitamin C content (mg·kg^{-1}) ± SE	Rank
BL-3	4640.2 ± 67.8 a[y]	1	185.9 ± 0.7 tu	37	121.4 ± 2.9 gh	17
BL-10	4381.7 ± 99.2 b	2	303.7 ± 0.7 f	9	120.0 ± 6.1 ghi	19
BL-6	3865.7 ± 48.6 c	3	319.2 ± 1.4 d	5	122.2 ± 1.5 gh	16
BL-14	3519.9 ± 70.7 d	4	308.1 ± 0.7 ef	7	147.6 ± 2.4 de	10
BL-12	3500.7 ± 34.0 de	5	273.3 ± 1.3 j	16	148.8 ± 6.9 de	9
BL-21	3429.8 ± 52.9 de	6	308.1 ± 0.7 ef	8	155.2 ± 3.0 bcd	7
Seyran	3418.3 ± 28.6 de	7	294.8 ± 0.7 g	10	137.1 ± 0 efg	12
BL-17	3402.4 ± 79.4 de	8	251.8 ± 0.7 l	19	116.0 ± 3.9 hij	20
BL-5	3333.3 ± 188.5 def	9	330.4 ± 3.0 c	3	95.8 ± 1.5 l	27
BL-19	3298.7 ± 43.8 efg	10	220.0 ± 5.9 q	29	103.1 ± 0.1 ijkl	24
Sarica	3196.5 ± 88.4 fgh	11	247.4 ± 0.7 lm	21	136.6 ± 1.6 efg	13
GV-42001	3196.5 ± 84.8 fgh	12	243.0 ± 0.7 mno	23	178.3 ± 1.7 a	1
BL-4	3195.0 ± 71.4 fgh	13	229.6 ± 2.7 p	26	143.5 ± 8.0 pdef	11
BL-16	3119.7 ± 59.9 ghi	14	221.5 ± 1.5 q	28	69.4 ± 6.3 pq	36
BL-22	3115.5 ± 57.4 ghij	15	280.0 ± 1.3 ij	15	114.7 ± 1.5 hijk	21
Medetli	3094.7 ± 51.1 hijk	16	243.7 ± 4.1 mn	22	68.4 ± 2.7 q	37
BL-25	3059.4 ± 26.6 hijk	17	198.5 ± 1.5 s	34	120.1 ± 4.5 ghi	18
Fiat	2924.3 ± 65.3 ijkl	18	320.7 ± 2.0 d	4	62.2 ± 2.6 qr	40
BL-20	2916.7 ± 90.0 jkl	19	200.7 ± 5.8 s	33	98.8 ± 1.3 jkl	25
BL-2	2912.5 ± 273 kl	20	264.4 ± 1.3 k	17	93.8 ± 1.3 lm	28
Balhan	2911.2 ± 73.3 kl	21	263.7 ± 0.7 k	18	177.8 ± 2.6 a	2
BL-18	2856.8 ± 102.8 l	22	290.4 ± 0.7 gh	11	74.89 ± 1.5 nopq	34
Lavi	2800.4 ± 61.5 lm	23	283.7 ± 2.7 hi	13	149.7 ± 5.2 cde	8
BL-24	2790.2 ± 40.7 lmn	24	342.2 ± 2.5 b	2	157.7 ± 4.4 bcd	5
BL-15	2786.7 ± 92.3 lmn	25	236.3 ± 0.7 nop	24	63.9 ± 6.5 qr	39
BL-27	2644.7 ± 67.3 mno	26	194.1 ± 4.1 s	35	97.6 ± 3.0 kl	26
BL-13	2591.1 ± 67.2 no	27	229.6 ± 4.9 p	27	127.1 ± 2.4 fgh	15
Moncayo	2550.6 ± 74.7 op	28	314.1 ± 4.5 de	6	166.9 ± 4.1 abc	4
Kirkagac-85	2511.4 ± 52.2 opq	29	175.5 ± 0 vw	39	70.9 ± 1.4 opq	35
Kirkagac-86	2383.2 ± 72.0 pqr	30	235.5 ± 2.2 op	25	134.7 ± 4.9 efg	14
BL-11	2373.6 ± 57.0 pqr	31	216.3 ± 2.0 qr	30	76.9 ± 3.8 mnopq	33
BL-8	2326.6 ± 44.8 qrs	32	288.1 ± 0.7 gh	12	156.8 ± 2.9 bcd	6
Sally	2273.1 ± 148.2 rs	33	357.8 ± 2.2 a	1	114.4 ± 3.6 hijk	22
BL-7	2153.2 ± 30.9 st	34	283.0 ± 2.0 hi	14	49.9 ± 2.60 r	41
Yakupbey	2062.6 ± 28.9 t	35	180.0 ± 7.1 uv	38	87.0 ± 4.4 lmno	31
Citirex	1973.3 ± 21.6 tu	36	118.5 ± 2.7 y	42	167.1 ± 1.5 ab	3
Sinem	1833.3 ± 47.6 uv	37	248.9 ± 2.2 lm	20	64.3 ± 0 qr	38
BL-26	1772.8 ± 47.9 uvw	38	200.7 ± 4.9 s	32	103.4 ± 8.4 ijkl	23
BL-9	1686.6 ± 141.6 vw	39	210.4 ± 0.7 r	31	89.8 ± 2.6 lmn	30
Hisar	1622.2 ± 36.0 w	40	168.9 ± 1.3 wx	40	86.5 ± 0.9 lmnop	32
BL-23	1479.2 ± 50.8 x	41	161.5 ± 1.5 x	41	48.4 ± 2.3 r	42
BL-1	1184.8 ± 40.0 y	42	193.3 ± 2.0 st	36	89.9 ± 1.3 lmn	29

[z]Lines are ranked by total water-soluble antioxidant capacity. Rankings for other parameters are also included.

[y]Values followed by different letters are significantly different at $P < 0.05$ as determined by Fisher's least protected significant difference.

with lowest and highest antioxidant capacity. Mean antioxidant capacity for the 42 lines was 2.79 mmol TE·kg^{-1}. In the literature, many different antioxidant capacity measurement methods have been used in melon including FRAP (fluorescence recovery after photobleaching), ORAC (oxygen radical absorbance capacity), and VCEAC (vitamin C equivalent antioxidant capacity).[18,24–30] Melon antioxidant capacity measured by the ABTS method yielded 1.20 mmol TE·kg^{-1} for cantaloupe and 0.65 mmol TE·kg^{-1} for honeydew melon.[28] Thus, higher antioxidant capacity was found in the types of melons tested in this work. When the melons were grouped based on type, it was seen that ananas, charentais, galia, and canary melons had the highest mean antioxidant capacities with values of approximately 2.90 mmol TE·kg^{-1} (Table 3). Kislik melons had the lowest antioxidant capacity with approximately 50% of the activity of the other types. There was also significant variation within each melon type. Galia and kirkagac types had the most variability in total water soluble antioxidant capacity with 2.6- and 2.0-fold differences between the highest and lowest lines, respectively (Fig. 1). Interestingly, for all three melon types for which both breeding lines and cultivars were examined (galia, ananas, and kirkagac), several breeding lines had significantly higher total water-soluble antioxidant capacity than widely-grown cultivars.

Total Phenolic Content

Total phenolic content in the melon lines ranged from 118.5 to 357.8 mg kg^{-1}, a 3-fold difference in content (Table 2). The galia cultivar 'Sally' had the highest phenolic content while another galia cultivar 'Citirex' had the lowest phenolic content. The mean phenolic content of the 42 lines was 248 mg kg^{-1} which is more than twice the phenolic content of honeydew melon (110 mg kg^{-1}) as determined by Chun et al.[24] These results suggest that the melon types examined in this work are richer in phenolic compounds than honeydew melon. When grouped by type, the types fell into two classes with four types having higher phenolic content than the others (Table 3). Thus, galia, ananas, kirkagac, and canary melons had approximately 1.4-fold greater phenolic content than kislik, charentais, and yuva melons. Within types there were many significant differences among lines (Fig. 2). As with total water-soluble antioxidant capacity, galia and kirkagaç types showed the most variation, 3- and 2-fold variations, respectively. For ananas and kirkagac melons, several breeding lines outperformed cultivars for total phenolic content.

Table 3 Mean values for melon lines grouped by type.

Melon type	Number cultivars	Mean antioxidant activity (μmolTE·kg^{-1}) ± SE	Mean phenolic content (mg·kg^{-1}) ± SE	Mean vitamin C content (mg·kg^{-1}) ± SE
Galia	14	2,973.2 ± 201.6 a[z]	257.7 ± 17.2 a	120.0 ± 80 b
Ananas	15	2,990.5 ± 108.2 a	251.0 ± 9.9 a	111.0 ± 90 bc
Kirkagac	7	2,458.4 ± 362.0 b	240.7 ± 24.2 a	103.2 ± 13 c
Canary	2	2,873.5 ± 322.9 a	278.5 ± 35.5 a	173.1 ± 60 a
Kislik	2	1,332 ± 147.2 c	177.4 ± 15.9 b	69.0 ± 21 d
Charentais	1	2,924.3 ± 65.3	180.0 ± 7.1	87.5 ± 40
Yuva	1	2,062.6 ± 28.9	161.5 ± 1.5	48.9 ± 20

[z]Values followed by different letters are significantly different at $P < 0.05$ as determined by Fisher's least protected significant difference.

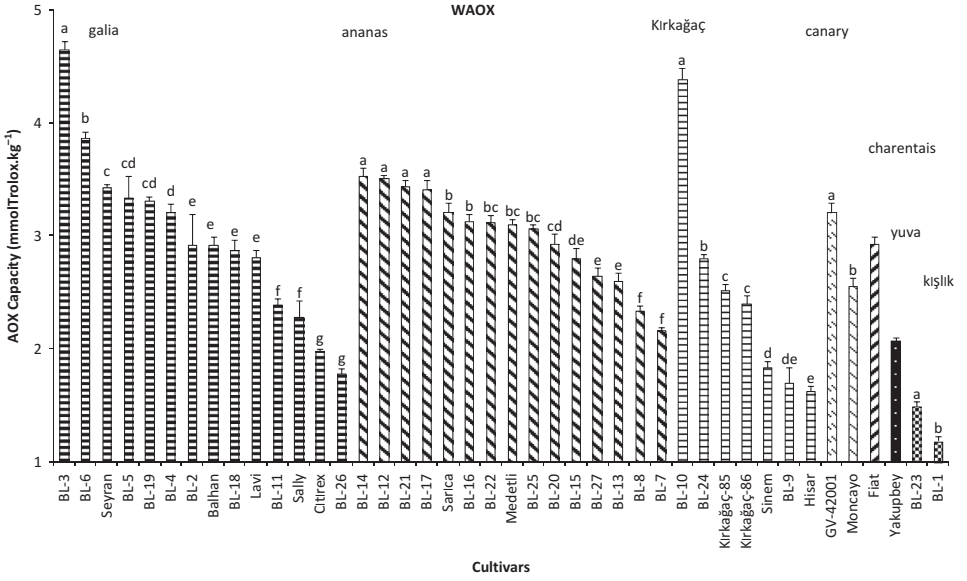

Figure 1 Antioxidant capacities of the melon lines grouped by type. Within each type, columns labeled with different letters are significantly different at $P < 0.05$ as determined by Fisher's least protected significant difference.

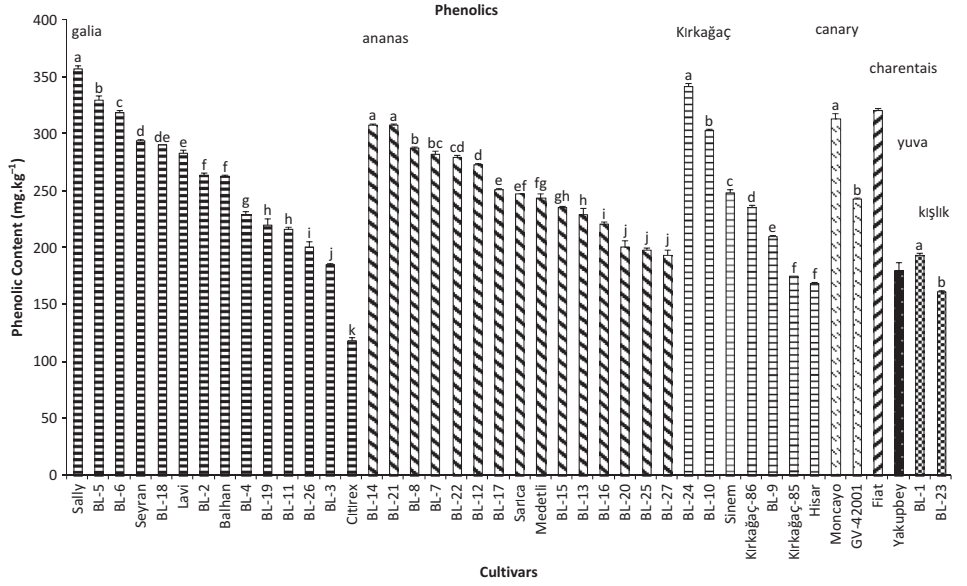

Figure 2 Phenolic contents of the melon lines grouped by type. Within each type, columns labeled with different letters are significantly different at $P < 0.05$ as determined by Fisher's least protected significant difference.

Vitamin C Content

Vitamin C content in the melons ranged from 48.4 to 178.3 mg kg^{-1} in BL-23 and 'GV-42001', respectively (Table 2). Thus, the melon lines had 3.6-fold variability with a mean vitamin C content of 112.1 mg kg^{-1}. In previous work, melon vitamin C content was reported as 40 mg kg^{-1} by Kevers et al.,[26] which is quite a bit lower than our mean value but consistent with our results considering that some of the melons in the current study had similarly low vitamin C contents (e.g., BL-23, BL-7). Overall, canary types had the highest vitamin C content with 173.1 mg·kg^{-1} (Table 3). Kislik, charentais, and yuva types were comparatively poor in vitamin C. Compared with total water-soluble antioxidant capacity and phenolic content, vitamin C content showed the most variation within types as shown in Fig. 3. There was 2.4, 3.1, and 2.5-fold variability in galia, ananas, and kırkagaç types, respectively. Breeding lines had higher vitamin C content than cultivars for both ananas and kirkagaç types, however, three of the five galia cultivars tested outperformed breeding lines for this parameter.

Correlation between Parameters

Some of the antioxidant parameters showed statistically signicant ($P < 0.05$) correlations between each other. There were fairly weak correlations between total antioxidant capacity and phenolic content ($r = 0.37$) and between total antioxidant capacity and vitamin C content ($r = 0.34$) but no significant correlation between vitamin C and phenolic contents. In previous work, other researchers observed significant correlations between antioxidant capacity and its components. Signicant positive correlations were seen between total antioxidant capacity and phenolic content in pepper,[31,32] tomato,[33] eggplant,[34,35] cranberry,[36] and blueberry.[37] In general, these correlations were stronger than the one

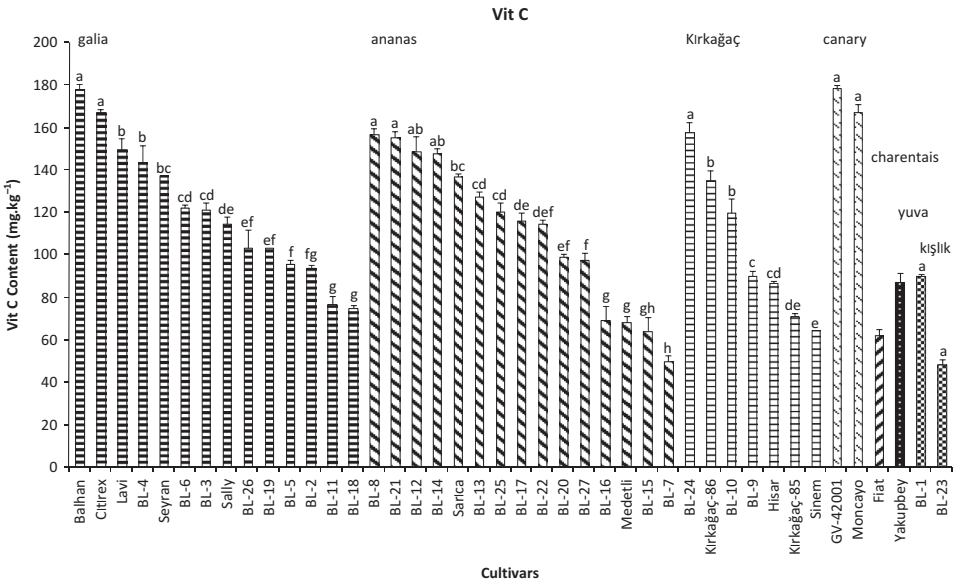

Figure 3 Vitamin C contents of the melon lines grouped by type. Within each type, columns labeled with different letters are significantly different at $P < 0.05$ as determined by Fisher's least protected significant difference.

observed for melon, perhaps because melon is less rich in phenolic compounds than these other fruits and vegetables.[19,26,30,38]

There were significant positive correlations between various horticultural traits. Thus, plant vigor was moderately correlated with fruit weight and shelf life. Fruit weight was also moderately correlated with fruit shape suggesting that rounder fruit tended to be smaller than oval/oblong fruit. Earliness was positively correlated with plant vigor, fruit weight, and shelf life indicating that lines producing later fruits grew more vigorously and had larger fruit that could be stored longer.

CONCLUSIONS

With increased consumer awareness of the link between diet and health, there is growing interest in the consumption and breeding of crops for health-related traits, such as antioxidant content. Compared with other common fruits, melon has moderate total water-soluble antioxidant capacity. When our values for melon are compared with previous work in other fruits using the same measurement method,[28] melon has higher total water-soluble antioxidant capacity than apple, banana, peach, and watermelon and similar capacity as cherry, grape, and pear. Berries and citrus fruits have the highest antioxidant capacity with values 1.5-fold (tangerine) to 7-fold (blackberry) higher than melon.[28] However, in Turkey, blackberries, raspberries, and blueberries are rarely found in local markets, are very expensive, and are usually eaten only as a special treat. In such countries, melon is a much better source for antioxidants than berries because it is cheap, available at even the smallest farmers' markets, and consumed in great quantities. Melon is poor in phenolic compounds with much lower phenolic content than commonly-eaten fruits, including apple, banana, orange, peach, and strawberry.[24] Vitamin C content of melon is also much lower than fruits reported to be rich in ascorbic acid (e.g., orange, strawberry, kiwifruit, banana) but higher than stone fruits (plum, apricot, cherry), apple, and pear.[26] As a first step toward breeding of improved antioxidant content in melon, it is essential that current cultivars and breeding line are surveyed to establish a base-line for improvement and to assess the genetic variability present for the parameters of interest. The melon lines grown in this work had considerable variation for all three antioxidant parameters with several breeding lines having significantly better antioxidant content than established cultivars. Breeding lines, such as BL-3 and BL-10 (galia and kirkagac types, respectively), with very high total water-soluble antioxidant capacity may be used in the development of high antioxidant melon cultivars. In addition, crosses between these lines and low antioxidant content lines also identified in this work can be used for the development of populations to map the genetic loci controlling antioxidant parameters.

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