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Preliminary Study on the Effects of Some Organic Fertilizers on Raspberry (Rubus idaeus L.) Variety Heritage

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ABSTRACT: *Soil structure, chemistry, and fauna are very important in terms of sustainable agricultural production, and it is inevitable to plan productionbased on these factors. In this context, the use of alternative ecosystem-friendly practices should be expanded in agricultural production instead of chemical fertilizers, which have harmful effects if used excessively. In this study, the effects of different fertilization (chemical, organic, and vermicompost) on the physicochemical properties of the "Heritage" cultivar of raspberry (**Rubus idaeus** L.), which is loved for its aroma and biochemical content, were investigated. Based on our results, chemical fertilization came to the fore in terms of fruit width (15.83 mm) and length (16.42 mm), while the highest values in terms of fruit weight (1.80 g) were obtained as a result of organic fertilization. In addition to citric acid (20749 mg L^{-1}), which has been identified as the dominant acid of the "Heritage" cultivar, chemical fertilization gave the best results in terms of tartaric acid (2615.54 mg L^{-1}), malic acid (477.71 mg L^{-1}) and titratable acidity (2.47 %) contents. For acetic acid (643.11 mg L^{-1}), ascorbic acid (201.08 mg L^{-1}) and oxalic acid (30.02 mg L^{-1}) contents high results were obtained from vermicompost application. At the same time, the highest total flavonoid content (11.78 mg quercetin L^{-1}) was determined in vermicompost application. The highest values in terms of total anthocyanin (1.54 µg cyan-3-glk g^{-1}) and total phenol (590.11 mg GAE L^{-1}) content were measured from chemical fertilizer application. Organic fertilization came to the fore in terms of antioxidant activity (95.24%), which is affected by many of the aforementioned metabolites. As a result of the study, it was determined that the application most affecting yield was organic fertilizer.*

***Key words: Rubus idaeus** L., organic fertilizer, quality, phenolic, Heritage.*

Farklı Organik Gübre Uygulamalarının Heritage Ahududu (Rubus idaeus L.) Çeşidinde Bazı Meyve Özelliklerine Etkisi Üzerine Ön Çalışma

ÖZ: *Tarımsal üretimin sürdürülebilir şekilde devam ettirilebilmesi bakımından toprak bünyesi, kimyası ve faunası oldukça önemli olup, üretimin bu doğrultuda planlanması kaçınılmazdır. Bu bağlamda fazla kullanılması halinde sakıncalı etkiler barındıran kimyasal gübreler yerine, tarımsal üretimde alternatif ekosistem dostu uygulamaların yaygınlaştırılması gerekmektedir. Bu çalışmada, sahip olduğu aroma ve biyokimyasal içerik bakımından sevilerek tüketilen ahududu (**Rubus idaeus** L.) türünün 'Heritage' çeşidinde farklı gübrelemelerin (kimyasal, organik ve vermikompost) fizikokimyasal özellikler üzerine olan etkileri araştırılmıştır. Sonuçlar doğrultusunda, meyve eni (15,83 mm) ve meyve boyu (16,42 mm) bakımından kimyasal gübreleme ön plana çıkarken, meyve ağırlığı (1,80 g) bakımından en yüksek değerler organik gübreleme sonucunda elde edilmiştir. 'Heritage' çeşidinin hakim asidi olarak tespit edilen sitrik asite (20749 mg L^{-1}) ek olarak, tartarik asit (2615,54 mg L^{-1}), malik asit (477,71 mg L^{-1}) ve titre edilebilir asit (% 2,47) içerikleri bakımından kimyasal gübreleme en iyi sonuçları vermiş, asetik asit (643,11 mg L^{-1}), askorbik asit (201,08 mg L^{-1}) ve oksalik asit (30,02 mg L^{-1}) içerikleri bakımından ise solucan gübresi* *uygulamasından yüksek sonuçlar elde edilmiştir. Aynı zamanda, en yüksek toplam flavonoid (11.78 mg Quercetin L^{-1}) miktarı da solucan gübresi uygulamasında belirlenmiştir. Toplam antosiyanin (1,54 µg siy-3-glk g^{-1}) ve toplam fenol (590,11 mg GAE L^{-1}) miktarı açısından en yüksek değerler kimyasal gübreleme uygulamasında ölçülmüştür. Tüm bu özelliklerin etki ettiği antioksidan aktivite (% 95,24) bakımından ise organik gübreleme ön plana çıkmıştır. Çalışma sonucunda verimi etkileyen uygulamanın organik gübre uygulaması olduğu belirlenmiştir.*

***Anahtar Kelimeler: Rubus idaeus** L., organik gübre, kalite, fenolik, Heritage.*

INTRODUCTION

The primary target in agriculture has become increased yield due to the continuous increase in population contrary to the shrinkage of agricultural areas. For this reason, there has been a serious increase in the use of mineral fertilizers in recent years. However, many adverse conditions such as salinization in the soil, heavy metal accumulation, loss of microorganism effectiveness, greenhouse effect, eutrophication in groundwater, and unbalanced nutrient distribution in the soil have resulted from excessive and unbalanced chemical fertilization, thereby incurring negative effects on the environment, human, animal, and ecosystem health (Sönmez and Sönmez, 2007; Savci, 2012; Dai *et al.,* 2018). It has been shown by many different studies that the products obtained from animals and plants fed from such sources have serious negative effects on human health (Winiarska-Mieczan, 2014; Cherfi *et al.,* 2015; Ward *et al.,* 2018).

Producers and consumers, who are organized by official institutions to support new environmentally-friendly agricultural policies and to be conscious of adverse conditions, have started to prefer agricultural products which do not pose a danger to human health, and which have been produced with methods that do not destroy nature (Wood *et al.,* 2006; Verbruggen *et al.,* 2010; Schmid *et al.,* 2011). In this context, the use of organic fertilizers and vermicomposting are among the most used methods to replace mineral fertilizers with harmful effects (Üçok *et al.,* 2019; Karlıdağ *et al.,* 2021).

In a study conducted with strawberries, it was found that plant biomass increased as a result of chicken manure and vermicompost fertilization compared to control and chemical fertilization. Also, it was stated that green manure and organic fertilization also contributed to the increase in yield (Polat and Çelik, 2008; Ateş *et al.,* 2019). In addition, it was reported that the leaf mineral content and antioxidant capacity of fruits were positively affected by organic-based nutrition products (Özkan and Yaman, 2009; Aneta *et al.,* 2013). On the other hand, while a similar positive effect was observed in a study on the morphological development of apple M9 rootstock (Eskimez *et al.,* 2020), it was reported that organic-origin nutrients facilitated the production of branched saplings in citrus species (Özbek and Dalkılıç, 2017). However, these effects are not stable and occur as a result of the cumulative effect of many variables such as ecology, genotype, and cultural processes (Bernacchia *et al.,* 2016).

In this study, the effects of different fertilization on some physicochemical properties of raspberry, which is defined as a functional product thanks to its specific phytochemicals, and which is consumed fresh thanks to its lovely aroma, and used in many areas in industry, were investigated.

MATERIAL and METHODS

Material

The trial was carried out in Karaağaç Village of Uşak province in 2019, and the "Heritage" cultivar was used as the material. The experiment was designed with 3 replications and each replicate consisted of 5 plants. Plants were planted in 2018 with within and between row spacing of 1.5 m × 0.6 m in the field. Plants were irrigated with drip irrigation and all cultural practices (pruning, fertilization, weed control, spraying, etc.) were completely applied throughout the growing period.

Soil analysis results of the study area are given in Table 1. According to the results of soil analysis, the soil of the experimental site has high alkaline characteristics with 15.00% active lime content. In addition, it is low in terms of organic material, nitrogen, and phosphorus content, respectively, but sufficient in terms of potassium content.

The experimental area has a typical continental climate with cold-moist winter and hot-dry summer. The weather was generally warmer than the long-term average during the experimental period possibly due to global warming. Although June and September received more precipitation than the long-term average, rainfall was lower in the remaining months and it was insufficient to meet plant water needs. Additionally, it was seen that precipitation occured irregularly (Table 2).

Method

Fertilizers applied and application methods

Considering the results of the soil analysis, the nitrogen contents of the fertilizers were taken as a basis while determining the amount to be applied per unit area for organic fertilizer applications (solid farm manure and solid vermicompost) and it was calculated as twice as 50% will be mineralized. The determined organic fertilizer amounts were accepted as equivalent to the nitrogen and phosphorus amounts in the fertilizers recommended as mineral in accordance with the soil analysis results. The required amount of fertilizers was determined and 40 kg/da ammonium nitrate, 17 kg/da triple super phosphate, 17 kg/da potassium sulfate for chemical fertilization, 1050 kg/da fertilizer for organic manure and the same amount for vermicompost were used. The organic manure and vermicompost used in the study were in solid form. Therefore, the fertilizers were applied to the root zone of the plants and mixed into the soil. Nitrogen fertilizers were divided into two applications (in March and April), and other fertilizers were applied only in March. The contents of organic fertilizer and vermicompost are given in Table 3 and Table 4.

Table 1. Soil analysis results of trial area.
Çizelge 1. Deneme alanının toprak analiz sonuçları.

pH	Salt Tuz (micros cm^{-1})	Lime Kireç (%)	Organic matter Organik madde (%)	Saturation İşba (ml)	Total N Toplam N (%)	Beneficial P Faydalı P (ppm)	Beneficial K Faydalı K (ppm)
7.90	310	15.0	1.69	50	0.085	0.38	512

Table 2. Average weather data of trial area in related months (Anonymous, 2019).
Çizelge. 2. Deneme alanının ilgili aylara ait ortalama hava durumu verileri (Anonymous, 2019).

Months / Aylar	Precipitation Yağış (mm)		Humidity Nem (%)		Temperature Sıcaklık (^0C)	
	2019	1939-2019	2019	1939-2019	2019	1939-2019
May / Mayıs	32.5	49.0	55.5	58.7	16.7	15.6
June / Haziran	38.6	27.8	58.6	57.0	20.9	19.9
July / Temmuz	9.3	14.9	47.1	52.2	22.8	23.4
August / Ağustos	3.9	10.6	42.7	49.7	24.4	23.4
September / Eylül	29.1	16.7	51.6	55.4	19.8	19.1

Table 3. Content of vermicompost.
Çizelge 3. Solucan gübresi içeriği.

Content İçerik	Unit Birim	Quantity Miktar
pH	0-14	7.2-7.4
Humidity / Nem	%	35-40
Organic matter / Organik madde	%	35-45
Organic carbon / Organik karbon	%	15-20
Total nitrogen (N) / Toplam azot	%	1.5-2.5
Total phosphorus (P_2O_5) / Toplam fosfor	%	2-2.5
Total potassium (K_2O) / Toplam potasyum	%	2.5-3
Calcium / Kalsiyum	%	5-6
Magnesium / Magnezyum	%	1-1.5
Iron / Demir	%	1-1.5
Manganese / Mangan	mg kg^{-1}	600-750
Boron / Bor	mg kg^{-1}	400-500
Chromium / Krom	mg kg^{-1}	0.041
Nickel / Nikel	mg kg^{-1}	36
Copper / Bakır	mg kg^{-1}	54
Zinc / Çinko	mg kg^{-1}	84

Table 4. Content of organic fertilizer.
Çizelge 4. Organik gübre içeriği.

Content İçerik	Quantity Miktar
pH range / pH aralığı	6.8-8.8
Organic matter / Organik madde	% 50
Total nitrogen (N) / Toplam azot	% 2
Total phosphorus pentaoxide (P_2O_5) / Toplam fosfor pentaoksit	% 2
Water-soluble potassium oxide (K_2O) / Suda çözünür potasyum oksit	% 2
Total (humic+fulvic) acid / Toplam (hümik+fülvik) asit	% 10
Maximum humidity / Maksimum nem	% 20
EC (Electrical conductivity) (ds m^{-1}) / Elektriksel iletkenlik	9.5
Carbon / Nitrogen (C N^{-1}) / Karbon / Azot	12.6

Determination of physico-chemical properties

For pomological characterization, 50 fruits were sampled homogeneously from the plants belonging to each parallel were not mixed with the others and the measurements were carried out to show the parallel. The measured fruits were converted into fruit juice by means of a juice extractor and chemical analyses were carried out using this juice. During harvesting, parameters such as the cultivar's unique color and size, sufficient softness, and easy separation of the fruits from the stems were taken into consideration as criteria and the harvests were made by one person to maintain consistency in the early morning hours of the day. Harvested fruits were transferred to the laboratory environment without loss of time. Fruit weight was measured using an electronic scale (Dikomsan) sensitive to 0.001 g, fruit width and fruit length were measured by a digital caliper (TCM) sensitive to 0.01 mm.

The soluble solid content (SSC) was measured with a digital refractometer (Hanna, HI 96801) and the results are given as a percentage (%) (Karaçalı, 2012). In the determination of titratable acidity, fruit juices were titrated with 0.1 N sodium hydroxide solution under the indicator of phenolphthalein, and the results were calculated according to Karaçalı (2012) and expressed as citric acid, which is the dominant acid of raspberry as %.

Determination of total phenolic content (TPC)

Total phenolic content of fruit juice was determined using the Folin-Ciocalteu technique. For this, 4500 µl of deionized water and 500 µl of undiluted Folin-Ciocalteu reagent were added to 1000 µl of sample juice. After 1 minute, 4000 µl of 7.5% (w v^{-1}) aqueous Na_2CO_3 was added. After 30 min of incubation at 30°C, absorbance was measured at 765 nm with a UV-Vis spectrophotometer and compared with a gallic acid calibration curve. Total phenols were determined as gallic acid equivalents (mg GAE g^{-1}) and values are presented as triplicate analyses (Kähkönen *et al.,* 1999).

Determination of total monometric anthocyanin (TMA)

The total anthocyanin content in the fruit was determined using the pH differential method according to Giusti *et al.* (1999). For the measurements of the diluted extracts, pH 1.0 (hydrochloric acid-potassium chloride) and pH 4.5 (acetic acid-sodium acetate) buffer solutions were prepared, and measurements were made at 510 and 700 nm wavelengths. Total anthocyanin content was calculated using the cyanidin-3-glycoside equivalent (molar extinction coefficient=29600) and absorbances were calculated using the formula $A=[(A_{510}–A_{700})_{pH\ 1.0} - (A_{510}–A_{700})_{pH\ 4.5}]$. Results are expressed as µg cyanidin-3-glycoside/g (µg cyan-3-glk g^{-1}).

Determination of antioxidant activity (AA)

Antioxidant activity determination (2.2-diphenyl-1-picrylhydrazyl) test was performed by slightly modifying the method developed by Brand-Williams *et al.* (Brand-Williams *et al.,* 1995; Thaipong *et al.,* 2006). DPPH Stock solution contained 24 mg DPPH dissolved in methanol. This mixture was transferred to a 100 ml flask and the volume was made up to 100 ml with methanol. The stock solution was stored at -18°C until later use. The final solution was obtained by mixing 20 mL of stock solution with 90 mL of methanol to obtain an absorbance of 1.1 ± 0.02 units at 515 nm using a spectrophotometer. For each sample, 300 µL of fruit juice was taken into a tube and 5.70 µL of antioxidant activity determination working solution was added and mixed. The mixture was allowed to react for one hour in a dark place. Then, absorbance was taken at a wavelength of 515 nm in a spectrophotometer. Antioxidant activity was calculated as a decrease in absorbance value using the following formula:

Antioxidant activity (%) = $(A_0 – A_1)/A_0 \times 100$

A_0: absorbance value of the control without sample.

A_1: absorbance of the mixture containing the sample.

Absorbance results were converted using the calibration curve of the ascorbic acid standard and expressed as ascorbic acid equivalents.

Determination of total flavonoid content (TFC)

Total flavonoid content of fruit juice was determined by aluminium chloride colorimetric experiment. Briefly, juice was mixed with 0.5 ml aliquots and standard solution (0.01-1.0 mg ml^{-1}) of quercetin, 2 ml of distilled water and then 0.15 ml of sodium nitrite solution (%5 $NaNO_2$, w v^{-1}). After 6 min, 0.15 ml (10% $AlCl_3$, w v^{-1}) solution was added. The solution was allowed to stand for an additional 6 min, after which 2 ml of sodium hydroxide (4% NaOH, w v^{-1}) solution was added to the mixture. The final volume was immediately adjusted to 5 ml by adding distilled water, mixed well and left to stand for another 15 min. The absorbance of each mixture was determined against the same mixture at 510 nm but without extraction as an extract. With the aid of the quercetin calibration curve, the total flavonoid content was determined as mg quercetin equivalent per gram. All determinations were performed in triplicate (n=3) (Chang *et al.,* 2002).

Determination of organic acids

The organic acid composition of the samples was determined by Agilent brand 1260 model HPLC by first passing the juice through a white band filter paper and then through a 25 micron injector tip filter.

For this purpose, ACE 5 C18 column (5 µm, 250 mm x 4.6 mm) and UV Detector were used. In the analysis performed in isocratic flow, 2% KH_2PO_4 solution adjusted to pH 2.3 with orthophosphoric acid was used as the mobile phase. Organic acids were determined at a wavelength of 214 nm in the analysis performed at 30°C at a flow rate of 0.9 mL min^{-1} and a 10 µl injection volume. Analysis time was 20 min. The amounts of organic acid components in the samples were calculated according to standard organic acid analysis results and results expressed as mg L^{-1} (Fadavi *et al.,* 2005).

Statistical analysis

The obtained data were subjected to one-way analysis of variance in the Minitab 17 package program, and significant differences were determined using the Tukey Multiple Comparison Test. Correlation analysis was used to determine the relationships between the characteristics (Zar, 2013).

RESULTS and DISCUSSION

Fruit width and fruit length values of "Heritage" cultivar varied within the limits of 15.70 mm (organic fertilizer) - 15.83 mm (chemical fertilizer) and 16.09 mm (organic fertilizer) - 16.42 mm (chemical fertilizer) and the effect of fertilizer type was found to be insignificant in terms of these properties. Contrary to expectations, the highest fruit weight value was measured as 1.80 g from the organic fertilizer application, where the lowest values were seen for width and length. This indicates that fruit volume increased with organic fertilization. As a matter of fact, the highest amount of soluble solid content (12.3%) observed in organically fertilized plants supports this situation. In addition, vermicompost with high organic matter content showed similar results with organic fertilizer in terms of fruit weight (1.74 g) and SSC (11.67%), while the lowest values in terms of these properties were measured as a result of chemical fertilization. However, with the exception of fruit weight, the differences between these characteristics were found to be insignificant (Table 5).

Table 5. Distribution of physicochemical properties according to fertilizer types.
Çizelge 5. Gübre çeşitlerine göre fizikokimyasal özelliklerin dağılımı.

Physico-chemical properties Fiziko-kimyasal özellikler	Chemical Kimyasal	Organic Organik	Vermicompost Vermikompost
Fruit width (mm)/Meyve eni	$15.83^{\pm 0.16A*}$	$15.70^{\pm 0.34A*}$	$15.73^{\pm 0.61A*}$
Fruit length (mm)/Meyve boyu	$16.42^{\pm 0.13A*}$	$16.09^{\pm 0.16A*}$	$16.17^{\pm 0.48A*}$
Fruit weight (g)/Meyve ağırlığı	$1.68^{\pm 0.04B**}$	$1.80^{\pm 0.05A**}$	$1.74^{\pm 0.06AB**}$
Soluble solid content (%)/ Suda çözünür kuru madde	$11.43^{\pm 0.12A*}$	$12.03^{\pm 0.15A*}$	$11.67^{\pm 0.75A*}$
pH/pH	$2.54^{\pm 0.05A*}$	$2.50^{\pm 0.02A*}$	$2.46^{\pm 0.05A*}$
Titratable acidity (%)/Titre edilebilir asit	$2.47^{\pm 0.08A*}$	$2.37^{\pm 0.04A*}$	$2.41^{\pm 0.08A*}$
Total phenolic content (mg GAE L^{-1})/ Toplam fenolik içerik	$590.11^{\pm 7.30A**}$	$575.68^{\pm 9.91AB**}$	$566.84^{\pm 3.91B**}$
Total flavonoid content (mg Quercetin L^{-1})/ Toplam flavonoid İçeriği	$8.81^{\pm 0.45B**}$	$9.68^{\pm 0.64B**}$	$11.78^{\pm 0.58A**}$
Total monometric anthocyanin (µg siy-3-glk g^{-1})/ Toplam monomerik antosiyanin	$1.54^{\pm 0.15A*}$	$1.37^{\pm 0.07A*}$	$1.38^{\pm 0.11A*}$
Antioxidant activity (%)/Antioksidan aktivite	$91.67^{\pm 1.70B**}$	$95.24^{\pm 1.13A**}$	$88.30^{\pm 1.69C**}$
Oxalic acid (mg L^{-1})/Oksalik asit	$22.04^{\pm 2.08B**}$	$24.33^{\pm 3.06B**}$	$30.02^{\pm 2.02A**}$
Tartaric acid (mg L^{-1})/Tartarik asit	$2615.54^{\pm 275.08A**}$	$2005.08^{\pm 82.61B**}$	$2354.76^{\pm 207.55AB**}$
Malic acid (mg L^{-1})/Malik asit	$477.71^{\pm 27.83A**}$	$461.22^{\pm 25.52A**}$	$335.08^{\pm 19.96B**}$
Ascorbic acid (mg L^{-1})/Askorbik asit	$137.67^{\pm 4.04C**}$	$189.33^{\pm 2.52B**}$	$201.08^{\pm 2.65A**}$
Acetic acid (mg L^{-1})/Asetik asit	$402.72^{\pm 44.5B**}$	$557.06^{\pm 34.8A**}$	$643.11^{\pm 38.36A**}$
Citric acid (mg L^{-1})/Sitrik asit	$20749^{\pm 1369.56A**}$	$17355^{\pm 580.45B**}$	$18230^{\pm 972.66AB**}$

*$p>0.05$: There is no significant difference between the groups indicated with the same letters/Aynı harflerle gösterilen gruplar arasında anlamlı farklılık yoktur.
**$p<0.05$: A statistically significant difference was found between the groups indicated with different letters./Farklı harflendirme ile gösterilen gruplar arasında istatistiksel anlamda farklılık bulunmuştur.

Since high acidity limits the activity of microorganisms, it is an important parameter in maintaining product stability. In addition, due to the acidic character of antioxidant-derived chemicals, the increase in fruit acidity also increases antioxidant activity (Mertoğlu and Evrenosoğlu, 2019). Raspberry is among the fruit species that attracts attention with its high acidity, and with this feature, it could be used successfully in many products in industry by preserving its stability for a long time. According to the results of the study, it was observed that chemical fertilization came to the fore in terms of titratable acidity (2.47 %), citric acid (20749 mg L^{-1}) which is found as the dominant acid of raspberry, followed by tartaric acid (2615.54 mg L^{-1}) and malic acid (477.71 mg L^{-1}) contents. Acetic acid, ascorbic acid and oxalic acid showed a similar trend and highest values were measured in the vermicompost group with values of 643.11 mg L^{-1}, 201.08 mg L^{-1}, and 30.02 mg L^{-1}, respectively. On the other hand, the lowest values of these chemicals were obtained in the chemical fertilizer group with values of 402.72 mg L^{-1}, 137.67 mg L^{-1} and 122,04 mg L^{-1} , respectively. Contrary to expectations, the pH value (2.54) was also high in the chemical fertilizer group with high acidity. The lowest pH value was determined in the vermicompost group (2.46).

It has been reported by many authors that raspberry is very rich and diverse in terms of bioactive compounds (Mazur *et al.,* 2014; Nile and Park, 2014; Gulcin *et al.,* 2011; Stajčićet *et al.,* 2012; Alibabićet *et al.,* 2018; Moore *et al.,* 2008; Maro *et al.,* 2013). For this reason, it is integrated into many products to increase their nutritional features. In addition, raspberry's positive health effects have been proven in many different fields from cosmetic products to medicine and it is widely used in these fields (Manganaris *et al.,* 2014; Hancock *et al.,* 2018). Although flavonoids, which are important in this context, were detected at the highest levels for the vermicompost group (11.78 mg quercetin L^{-1}), chemical fertilization came to the fore in terms of total anthocyanin (1.54 µg siy-3-glk g^{-1}) and total phenol (590.11 mg GAE L^{-1}) contents. The lowest values in terms of TPC and TFC properties, in which statistical significance was determined, were observed in the groups treated with vermicompost (566.84 mg GAE L^{-1}) and chemical fertilizers (8.81 mg quercetin L^{-1}), respectively. In terms of these properties, organic fertilization, which is in the middle group, showed the best result in terms of antioxidant activity (95.24%), while the lowest antioxidant activity was obtained from vermicompost application (88.30%).

Citric acid was reported as the dominant acid of different raspberry cultivars by Dincheva *et al.* (2013) and Ponder and Hallmann (2020), and its titratable acidity was reported to be around 2% in cultivars including "Heritage" (Yang *et al.,* 2020). Among the pomological features, fruit width, length, and weight characteristics were reported to vary between 15.88 to 17.76 mm, 16.21 to 18.85 mm, and 1.46 to 2.30 g in the "Heritage" cultivar, while SSC was determined as 10.23% to 13% (Pehluvan and Güleryüz, 2012; Balcı and Keles, 2019; Güneş and Küçükhüseyin, 2019). Although it is thought that the results obtained are generally compatible with the literature, features such as differences in climate and soil characteristics, geographical condition of the cultivation area, harvest type and time, storage or processing of the product, and differences in the method or period of cultural processes applied cause significant differences on the final shape and content of products (Stavang *et al.,* 2015; Çelik and İslam, 2019; Çolak and Sağlam, 2019).

It is assumed that low molecular weight organic compounds such as humic and fulvic acids may be easily taken up by plants and these compounds have a hormone-like effect by increasing the permeability of the cell membrane (O'Donnell, 1973; Casenave de Sanfilippo *et al.,* 1990; Konova *et al.,* 1996; Erdal *et al.,* 2000). In addition, it is stated that in parallel with the increase in the amount of organic matter in the soil, the capacity of anion and cation exchange increases, and this increase is important in plant nutrition (Yuan *et al.,* 2014; Yuan *et al.,* 2016). On the other hand, minerals that are absolutely necessary for plant life are actively involved in almost every physiological event (Bhatla and Lal, 2018; Lambers and Oliveira, 2019). In this context, it should be stated that these two different product groups are not substitutes for each other, they are complementary to each other. When the studies on raspberry are examined, it is reported that there are no serious differences between traditional and organic cultivation, and the results vary even according to the cultivar and year (Valentinuzzi *et al.,* 2018; Frias-Moreno *et al.,* 2019; Ponder and Hallmann, 2020; Anjos *et al.,* 2020). Also, Frias-Moreno *et al.* (2021) reported that organic fertilization increased antioxidant defense mechanisms and bioactive compound production by inducing oxidative stress and improved antioxidant capacity in raspberry. In this study, the highest fruit weight and antioxidant activity results were obtained from organic fertilizer application. Despite this, generally better results were obtained compared to the chemical fertilizer application group. This situation could be interpreted as organic fertilizers need a certain time after the application time in order to fulfill their function. In addition, yield is an important parameter in the distribution of assimilation products and is reflected in the results.

A strong positive correlation was determined between total phenol content and pH (0.76***) and SSC (0.83***). A strong positive correlation was found between SSC and malic acid, an organic acid (0.87***). There was a positive correlation between TEA and total anthocyanin content, oxalic acid, and acetic acid, 0.61**, 0.41*, and 0,44*, respectively. A high level of positive correlation was found between total flavonoid content and ascorbic acid (0.65**), DPPH, and malic acid (0.65**). A positive correlation was found between oxalic acid and acetic acid (0.94***), tartaric acid and citric acid (0.52**), ascorbic acid and acetic acid (0.42*) levels (Table 6).

A high level of positive correlation was found between fruit width and fruit length (0.59***). In plants, an increase in cell number and then cell enlargement are observed following fertilizer application. The coexistence of transverse and longitudinal development during cell expansion could explain the relationship between these features. An increase in cell volume is known to increase fruit weight. From this point of view, a positive relationship was determined between fruit weight and fruit width (0.47*) and fruit length (0.49*). Our results in this respect are in agreement with previous studies on different fruit species (Sarıdas *et al.,* 2017; Kahya and Selçuk, 2019).

CONCLUSIONS

In this study, the effects of different fertilization on the physicochemical properties of the "Heritage" cultivar raspberry were examined in terms of fruit quality and some biochemical properties. It has been observed that chemical fertilization has come to the fore for its positive effects on physicochemical properties. It was determined that chemical fertilization and vermicompost applications were effective on organic acid content, and organic fertilizer application was effective on fruit weight and antioxidant activity. When evaluating the results of these findings, it should be taken into account that a certain time must pass after the application of organic fertilizers to fulfill their functions and that they have long-term effects. In line with the results obtained, organic fertilizer application can be recommended in terms of yield increase and sustainability.

Table 6. Correlation coefficients among the investigated characteristics
Çizelge 6. Araştırılan özellikler arasındaki korelasyon katsayıları.

	FWe	FL	FWi	pH	SSC	TA	TPC	TFC	TMA	AA	OA	TA	MA	AsA	AcA
FL	0.49*														
FWi	0.47*	0.59**													
pH	0.32	0.42*	0.19												
SSC	-0.09	0.44*	0.09	0.54**											
TA	-0.28	0.10	-0.44	0.25	0.52**										
TPC	-0.08	0.37	0.23	0.76***	0.83***	0.35									
TFC	0.32	-0.18	0.15	-0.46*	-0.50***	-0.47**	-0.75***								
TMA	0.36	-0.55**	-0.59**	0.24	0.26	0.61**	0.31	-0.23							
AA	0.15	-0.06	0.09	0.38	0.24	-0.34	0.44*	-0.54**	-0.06						
OA	0.55**	-0.33	-0.73***	-0.62**	-0.02	0.41*	-0.43*	-0.08	0.18	-0.41*					
TA	0.31	-0.06	0.30	0.25	0.12	0.10	0.22	-0.09	0.14	-0.22	-0.26				
MA	0.11	0.41*	0.13	0.65**	0.87***	0.23	0.86***	-0.82***	0.14	0.65**	-0.26	-0.12			
AsA	0.33	-0.16	-0.12	-0.63**	-0.54**	-0.46*	-0.85***	0.65**	-0.40*	-0.28	0.37	-0.41*	-0.53**		
AcA	-0.29	-0.18	-0.68**	-0.55**	0.07	04.4*	-0.37	-0.13	0.14	-0.29	0.94***	-0.51**	-0.10	0.42*	
CA	-0.79***	-0.11	0.13	-0.07	0.30	0.10	0.43*	-0.45	0.09	0.06	0.05	0.52**	0.15	-0.61**	-0.16

FWe: Fruit weight (Meyve ağırlığı), FL: Fruit length (Meyve boyu), FWi: Fruit width (Meyve eni), SSC: Soluble solid content (Suda çözünür kuru madde), TA: Titratable acidity (Titre edilebilir asitlik), TPC: Total phenolic content (Toplam fenolik içerik), TFC: Total flavonoid content (Toplam flavonoid İçeriği), TMA: Total Monomeric Anthocyanin (Toplam Monomerik Antosiyanin), AA: Antioxidant activity (Antioksidan aktivite), OA: Oxalic acid (Oksalik asit), TA: Tartaric acid (Tartarik asit), MA: Malic acid (Malik asit), AsA: Ascorbic acid (Askorbik asit), AcA: Acetic acid (Asetik asit), CA: Citric acid (Sitrik asit)

*$p<0.05$, **$p<0.01$, ***$p<0.001$

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