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Determination of Yield and Quality Characteristics of Blueberries Grown in Pot and Raised-Bed in Soilless Culture

Topraksız Ortamda Saksı ve Masurada Yetiştirilen Maviyemişlerin Verim ve Kalite Özelliklerinin Belirlenmesi

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DETERMINATION OF YIELD AND QUALITY CHARACTERISTICS OF BLUEBERRIES GROWN IN POT AND RAISED-BED IN SOILLESS CULTURE

ABSTRACT

Like other *Vacciniums*, blueberries love acidic soils for growing. But new and alternative soilless growing systems developed for new areas with ecological advantages. Blueberries have small bushy plants and they began to be grown in pot and raised-bed using special substrates. In the present study, yield and berry characteristics of five northern highbush blueberry cultivars ('Bluecrop', 'Brigitta', 'Denise Blue', 'Patriot', and 'Blugold') were studied under soilless culture. They planted in pot with acidic peat moss and raised beds under open-air conditions. Plant phenology, growth, development, yield, and berry quality characteristics of the cultivars were determined. Budburst begins at the end of the last week of February for both growing areas in all cultivars. Raised-bed growing cultivars bloomed earlier than pot-grown ones. Fruit coloring starts within the second week of June. Pot-grown blueberry cultivars were the best yielded than raised-bed ones and 'Patriot' had the highest yield (955.14 g/bush) while 'Bluegold' had the largest berries (17.45 mm). Raised-bed-grown cultivars gave higher %TSS and lower acidity than pot-grown ones.

Keywords: Blueberry, *Vaccinium Corymbosum*, Yield, TSS, Firmness, Berry Weight.

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TOPRAKSIZ ORTAMDA SAKSI VE MASURADA YETİŞTİRİLEN MAVİYEMİŞLERİN VERİM VE KALİTE ÖZELLİKLERİNİN BELİRLENMESİ

ÖZ

Diğer *Vacciniumlar* gibi maviyemişler de yetişmek için asidik toprakları sever. Ancak ekolojik avantajları olan yeni alanlar için yeni ve alternatif topraksız yetiştirme sistemleri geliştirilmiştir. Maviyemişler küçük ve çalımsı bitkilere sahip olduklarından özel substratlar kullanılarak saksı ve yükseltilmiş seddelerde yetiştirilmeye başlanmıştır. Bu çalışmada, beş adet kuzeyli yüksek boylu maviyemiş çeşidi ('Bluecrop', 'Brigitta', 'Denise Blue', 'Patriot' ve 'Blugold') topraksız kültür altında saksı ve masuralarda yetiştirilerek verim ve kalite özellikleri incelenmiştir. Açık arazi koşullarında asidik torf içeren saksı ve yükseltilmiş masuralara dikilen maviyemişlerde bitki fenolojisi, büyüme-gelişme, verim ve meyve kalitesi özellikleri belirlenmiştir. Tüm çeşitlerde, her iki yetiştirme alanı için de tomurcuklanma Şubat ayının son haftasının sonunda başlamıştır. Yükseltilmiş masuralarda büyüyen ma-

viyemiş çeşitlerinde çiçeklenme saksıda yetişenlere göre daha erken gerçekleşmiştir. Meyvelerdeki renklenme genelde Haziran ayının ikinci haftasında başlamıştır. Saksıda yetiştirilen maviyemiş çeşitlerinin verimi masuralarda yetişenlere göre daha yüksek olmuştur. Saksıda yetişen 'Patriot' çeşidi en yüksek verime (955.14 g/çalı) sahipken 'Bluegold' en büyük meyvelere (17.45 mm) sahip olmuştur. Masurada yetişen maviyemiş çeşitleri saksıda yetiştirilenlere göre daha yüksek kurumadde içermiş ve asitlikleri de düşük kalmıştır.

Anahtar Kelimeler: Maviyemiş, *Vaccinium Corymbosum*, Verim, SÇKM, Sertlik, Tane Ağırlığı.

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1. INTRODUCTION

Blueberries have many health benefits and they are classified in the *Vaccinium* genus of the *Ericaceae* family with cranberry, lingonberry, Caucasian whortleberry and bilberry. Actually, blueberry is a "superfood" with its high nutritional content, vitamins and minerals (Kalt et al., 2020). The cultivation of *Vacciniums*, which can grow in acidic soils, has been limited until recent years. Since blueberries, which have increasing demand worldwide, grow in acidic and non-calcareous soils, their cultivation in soil has not spread much. Because it is not possible to find natural acidic soils everywhere in the world. For this reason, the production of highbush blueberries is rapidly increasing worldwide by using special and acidic environments in pot or raised soil beds. Blueberries grown in soilless environments may have high productivity after the year of planting. The nutrients and moisture content of the pot grown blueberries can be kept under full control, and the bushes can develop well without stresses and they produce quality fruit (Fang et al., 2020; Heller and Nunez, 2022). Since the number of plants per unit area can be increased 2-3 times compared to planting in the soil, the yield also increases (Çelik and Seydioğlu, 2019). Acidic peat and coconut-fiber with high-water holding capacity, provides a very suitable growing environment for soilless blueberry cultivation (Fang et al., 2020; Schreiber and Nunez, 2021). On the other hand, peat-containing mixtures become widely used in both pot or raised soil beds. These substrates have good cation exchange capacity, low phytotoxic substances with low volume densities, so they are widely used to increase fruit yield and quality (Meng et al., 2022). In the last decade, blueberries have become one of the main berry fruits worldwide. Commercially produced highbush (*Vaccinium corymbosum* L.), lowbush (*Vaccinium angustifolium* Ait.) and rabbiteye (*Vaccinium ashei* L.) blueberries are increasing in both Europe and Türkiye in terms of planting areas and production. Data shown that 1.860.000 tons of blueberries produced in an area of 248.548 hectares in the world and China ranks first with 525.310 tons, while Peru (299.670

tons), USA (277.630 tons), Chile (166.350 tons), Canada (76.150 tons), Mexico (75.870 tons), Spain (69.190 tons), Poland (68.500 tons), Morocco (47.070 tons) and South Africa (30.500 tons) are among the top ten countries (Brazelton et al., 2023; Çelik, 2024). The blueberry planting area that we brought to Türkiye in the early 2000s was 5 decares and production was 2 tons until 2003, while in 2023 the area reached 5454 decares and production reached 10315 tons. Blueberry production continues in soil in 15 provinces and in pot as soilless culture in 18 provinces in the Black Sea, Thrace, Marmara, Aegean, Mediterranean, Central Anatolia and Southeastern Anatolia regions of Türkiye. Blueberry, which grows in soil in provinces where soil conditions are suitable, is grown intensively in pot in the Mediterranean Region where soil conditions are not suitable but very early or very late fruit harvest is made by taking advantage of the ecology (Çelik, 2018; Çelik, 2024; Ünal et al., 2023).

Blueberry soilless culture getting increase in Mediterranean climate under greenhouse and in open air under different-colored and anti-hail shade-net for earliness both local and foreign market. Because world blueberry consumption is increasing day by day and the price of blueberries is increasing in parallel with the increase in demand (Çelik, 2024; Ünal et al., 2023). Although blueberries were cultivated in the early 1900s, the first studies on the adaptation and fruit characteristics of northern highbush blueberry cultivars in Türkiye were started in Rize in the 2000s. With these studies, the cultivation of the northern highbush blueberry species introduced and developed along Black Sea Region with natural acidic soils (Çelik, 2019). While productivity in blueberries depends on climatic and ecological conditions, quality is related to soils (Retamales and Hancock, 2018). Low or high temperatures during the winter dormancy of blueberries and flowering time and water deficiency can reduce fruit set, decrease size and yield. All these adverse conditions can also have an adverse effect on the number and differentiation of flower buds (Pavlovski, 2010). Blueberries, which love acidic soils, differ from other fruit species because blueberry roots, which work together with mycorrhizae, do not have absorbent hairs. Blueberries can grow well in sandy, sandy-loam and fertile soils that are well-drained, airy, rich in organic matter and have a pH value between 4.2-5.5 (Strik and Fin, 2008). Iancu et al. (2010) determined that the use of manure and peatmoss into raised-bed during blueberry planting increased the %TSS. Strik et al. (2012) stated that the planting system had no effect on berry firmness, but firmness increased in blueberries fertilized with high levels of fish waste, and also yield per plant with firmness increased in blueberries planted in raised-bed compared to flat planting. Çelik (2003) and Çelik (2009) stated that northern highbush blueberry varieties planted in the acidic soils showed medium vigor and their yield per plant varied between 455.21 g (Berkeley) and 2567.80 g (Ivanhoe). He also found that the berry weight varied between 0.94 g (Northland) and 2.41 g (Ivanhoe). It is evidence that yield per bush, %TSS, acidity and

ripening periods may vary according to the blueberry variety and altitude (Çelik, 2009a; Çelik, 2009b; Çelik and Acar, 2021). Heiberg and Lunde (2006) determined that plant height and fruit yield were significantly affected in blueberry grown in peat, sand, pine bark and perlite environments mixed in different ratios. The researchers revealed that the components in the growth and cultivation areas of the 'Bluecrop' and 'Nui' blueberry varieties showed different reactions and that these varieties developed better in pot. Substrate temperatures (Spiers, 1995), ratio of pine bark, sphagnum peat moss, coco coir, Douglas fir bark, perlite and adequate water and nutrients (Voogt et al., 2014), physical and chemical properties of substrates (Retamales and Hancock, 2018) may affects to the pot or raised-bed growing blueberries. We know that harvest time may be delayed in pot cultivation and blueberry harvested from pot can be stored in higher quality compared to others (Eldik, 2015). Today both northern and southern highbush blueberries could be grown in pot with soilless culture in anywhere (Çelik and Seydioğlu, 2019; Hız et al., 2019; Fang et al., 2020; Çelik and Acar, 2021). Fisher (2012) attributed the suitability of southern highbush blueberries for cultivation in pot and they found that they form strong and abundant branches, form thin and abundant leaves, have a compact appearance and bloom abundantly, and are also advantageous in terms of resistance to diseases. The substrates used in pot consist of a mixture of substances such as low pH peat, sawdust or coniferous sawdust (Ochmian et al., 2010), pine bark (Krewer et al., 2002; Nicolas et al., 2016; Mejia et al., 2016), coal ash, compost and leaf compost or shredded coconut shells and perlite (Black and Zimmerman, 2002). Researchers recommended the varieties 'Bluecrop' and 'Nui' for growing blueberries in pot in greenhouses. Smolarz (1985) stated that the harvest season can also be changed by growing blueberries in pot.

The main purpose of this study is to determine the growth and development performances as well as yield and quality characteristics of some northern highbush blueberry varieties grown in pot and raised-bed in open fields. For this aim, 5 northern highbush blueberry varieties ('Bluecrop', 'Brigitta', 'Denise Blue', 'Patriot' and 'Blugold') were used and they planted both in pot and raised beds with soilless culture techniques.

2. MATERIAL AND METHODS

This study was carried out in the Research and Application area of the Faculty of Agriculture, Ondokuz Mayis University. The experiment was carried out at an altitude of 195 m above sea level and 2.8 km from the sea level at 41°21'52 N latitude and 36°11'29 E longitude. In the experiment, 3-year-old northern highbush blueberry varieties 'Bluecrop', 'Brigitta', 'Denise Blue', 'Patriot' and 'Blugold' were planted in 50 L pot and raised-bed covered with mulch made of black woven jute material. Lithuanian acidic peatmoss was used as a medium both in the pot and

in the raised-bed. The pH value of the Lithuanian acidic peat used in the pot and raised-bed experiment is 4.5-4.8 and the salt ratio is below 0.2. There is no NPK in this substrate containing trace elements and iron. Raised-bed were prepared to be 60 cm wide and 40 cm high. Plants were planted in raised-bed with 2x1 m distances between and in rows, while potted plants were placed in the trial area at the same intervals and distances (Fig. 1). During the trial, drip irrigation was done with pH-adjusted water, and from May on, the plants were shaded with a green shade cover that provided 35% shade, while bird control was also provided. The trial was conducted between 2017 and 2019.

Figure 1. Blueberry varieties grown in pot and raised-bed with black fabric mulch

The substrate used for both raised-bed and pot was mixed with 100 g of slow-released fertilizer (Osmocote-Pro, 17-11-10+2Mg0+Te, 8-9 months) per plant, while additional fertilization was made with ammonium sulphate and compound fertilizer (10:10:10) as 3 times with a total of 50 g per plant in May, June and July. The experiment was established according to the split plot design in randomized blocks with 3 replications and 5 plants in each replication. In the experiment, the cultivation area was placed in the main plots and the varieties were placed in the sub-plots. Phenological stages, yield, berry weight (g), firmness (N) and diameter (mm), and TSS (%), acidity (%) and pH were determined. The flower, fruit and leaf bud development phenology were determined by Çelik (2012) schema. The data obtained from the experiment were subjected to variance analysis with the SPSS 16.0 for Windows package program, and the differences between the means were separated with the DUNCAN multiple range test at the $p<0.05$ level.

3. RESULTS AND DISCUSSION

3.1. Phenology

The flower and leaf buds and berry growth phenological stages for both pot and raised-bed planted northern highbush blueberry cultivars are given at the Table 1. In both potted and raised-bed planted blueberries, flower bud burst in the last week of February. There are 3- or 4-days difference in flower bud bursting times between cultivars. The earliest bud burst was on February 24 at the 'Bluecrop', 'Patriot' and 'Bluegold' varieties grown in both pot and raised-bed. Pot planted 'Brigitta' variety show the latest flower bud burst on March 2. Full bloom occurred in April in both potted and raised-bed plants. However, the raised-bed planted varieties were earlier for full bloom than the pot planted ones. This may be due to the pot being oriented north and the raised-bed being oriented south. Because, while full bloom occurred on April 3 ('Bluecrop', 'Bluegold'), April 5 ('Denise Blue') and April 12 ('Brigitta') in raised-bed planted blueberries, it was observed that the pot planted blueberries bloomed later, such as on April 10 ('Bluecrop' and 'Patriot') or even April 19 ('Denise Blue' and 'Brigitta'). Berry coloring known as veraison occurred in the first week of June for raised-bed grown cultivars and second week of June for the pot planted ones.

The earliest berry colored cultivar was 'Patriot' (29 may) grown in raised bad and the latest one was 'Brigitta' (19 June) grown in pot (Table 1). It is known that full bloom and ripening with coloring may vary depending on variety, chilling requirement, ecology and direction (Çelik, 2012; Çelik and Ağaoğlu, 2013). Retamales and Hancock (2018) also showed that flower buds of blueberry burst early than leaf buds and this situation may be affected by ecology, cultivar and chill hours. They also revealed that the leaf bud burst may start 7-12 days after the flower bud burst and it differs according to the varieties. Researcher also found that the bursting in the leaf buds of the blueberries grown in pot may be earlier than those in the raised-bed. They believe that this is due to the sun and temperature. Conversely, we determined that full bloom, berry set, veraison and blue color in berries occurred earlier in blueberry cultivars grown in the raised-bed than those in pot. This situation is literally about sun exposure, shade and direction (Retamales and Hancock, 2018; Çelik, 2012; Çelik and Ağaoğlu, 2013). It is also known that day length and sunny hours does not only affect flower bud formation, it also affects the uniform flowering, berry development and maturation. These conditions also effect to flowering time and bud bursting may decrease %50 when sun duration decreases from 10 to 8 hours (Darnell and Davies, 1990). Çelik (2018) also found that there were differences between the varieties in terms of phenological stages, earliness, maturity, coloration, berry content and harvest time. This situation is also reported by Ciordia et al. (2002).

Table 1. Phenological stages of flower bud, leaf bud and berry development of southern highbush blueberry cultivars grown in pot and raised-bed*

Cultivars	Flower bud burst	Flower bud tight cluster	Full bloom	Leaf bud late green tip	Leaf bud shoot expansion	Berry green fruit set	Berry fruit coloring
			Pot				
Bluecrop	24 February	02 March	10 April	28 February	14 March	18 April	12 June
Bluegold	24 February	07 March	12 April	03 March	28 March	24 April	16 June
Patriot	24 February	02 March	10 April	03 March	28 March	18 April	12 June
Denise Blue	27 February	08 March	19 April	10 March	01 April	28 April	03 July
Brigitta	02 March	10 March	19 April	3 March	28 March	28 April	19 June
			Raised-bed				
Bluecrop	24 February	02 March	03 April	01 March	09 March	12 April	02 June
Bluegold	24 February	02 March	03 April	06 March	14 March	12 April	02 June
Patriot	24 February	02 March	12 April	01 March	13 March	21 April	29 May
Denise Blue	27 February	06 March	05 April	06 March	15 March	18 May	02 June
Brigitta	27 February	08 March	12 April	06 March	15 March	21 April	07 June

**: Determined according to the scale specified by Çelik (2012).*

3.2. Yield, Berry Weight, Firmness and Diameter

It was found that there were significant differences in yield per plant, berry weight, firmness and diameter values in pot and raised-bed grown blueberry varieties according to the growing location and varieties. Chiabrando et al. (2009) proved that firmness is one of the most attribute in quality traits, when blueberries arrive at market. Lobos et al. (2018) also stated that there may be a significant difference in firmness between the berries that are picked when they have reached their full blue color and the fruits that are kept on the bush. Firmness is still the most relevant quality trait for fresh blueberries (Contador et al., 2015) and firmness is the major barrier that limits export to distant markets (NeSmith et al., 2002)

The yield per plant of potted blueberry varieties was much higher than those grown in the raised-bed and 'Denise Blue' variety ranked first with 955.14 g yield per plant. This variety was followed by pot grown 'Patriot' (937.41 g), 'Bluecrop' (921.84 g) and 'Bluegold' (918.08 g) varieties. While the most productive variety in raised-bed grown blueberry varieties was 'Denise Blue' with 649.15 g. yield, the yield of other varieties was very low. The least productive variety based on growing environment and varieties was 'Bluegold' variety grown in raised-bed with 178.87 g. On the other hand, it was found that the total yield in the pot (871.29 g/plant) was higher than the total yield in the raised-bed (329.43 g/plant). When the blueberry varieties were considered in terms of total yield, it was found that the 'Deni-

se Blue' variety had the highest (802.14 g/plant) and the 'Brigitta' variety had the lowest (461.57 g/plant) total yield; this was followed by the 'Bluegold' (548.47 g/plant) and 'Patriot' varieties (590.41 g/plant) (Table 2, Figure 1 and Figure 2). The most important criterion examined in the adaptation abilities of blueberry varieties is the yield value obtained per plant (Çelik, 2012; Çelik and Ağaoğlu, 2013; Retamales and Hancock, 2018). Çelik (2009b), stated that the yield in blueberries may vary according to the varieties and he determined that the 'Ivanhoe' variety was the highest yielding variety (2567.80 g/plant) while the 'Berkeley' was the lowest yielding variety (455.21 g/plant) in the İkizdere district of Rize with the 'Berkeley', 'Ivanhoe', 'Jersey', 'Northland' and 'Rekord' varieties of high-growing blueberries of northern highbush. Heiberg and Stabhaug (2006) observed that the 'Bluecrop' variety, which they grew in pot using different environments for three years, yielded 326 g of fruit per plant. They also determined that varieties reacted differently according to the growing place and that blueberries grown in pot developed better and were more productive. In blueberries, yield per plant can be affected by factors such as variety, plant age, pH, plant nutrition, substrate type, ecology, mulch type, photoperiod, number of shoots and flower buds, and berry weight (Austin and Bondari, 1990; Heiberg and Stabhaug, 2006; Çelik, 2009a; Çelik, 2009b; Retamales and Hancock, 2018).

In the present study, we determined that the berry weight of blueberries grown in pot was higher than those grown in raised-bed. Accordingly, the largest fruits were obtained from the 'Denise Blue' variety grown in pot with 2.72 g, followed by 'Patriot' (2.27 g) grown in pot and 'Denis Blue' (2.17 g) grown in raised-bed. On the other hand, the 'Bluecrop', 'Bluegold' and 'Patriot' varieties grown in raised-bed were ranked as the varieties with the lowest fruit weights with 1.14, 1.22 and 1.32 g, respectively (Table 2). When the average fruit weights of the varieties were taken into consideration, it was determined that the 'Denise Blue' variety had the largest fruits with 2.44 g, while the 'Bluecrop' variety had the lowest fruit weight with 1.29 g (Figure 3). The berry firmness measured in Newtons also varies according to the blueberry growing environment and varieties, while the hardest berries (88.68 N) were obtained from the 'Brigitta' variety grown in pot, while the 'Denise Blue' variety grown in pot had the softest fruits with 52.45 N. This situation was interpreted as a variety characteristic. Berry size also appears as diameter and is measured with different scales and circles. Accordingly, the variety with the highest berry diameter was the 'Patriot' variety grown in pot with 17.45 mm. It was determined that the fruit diameter of the varieties grown in pot was higher than those grown in raised-bed, and the 'Bluecrop' variety grown in raised-bed produced the smallest berry diameter with 13.53 mm (Table 2, Fig. 3 and 4).

Table 2. Yield and berry characteristics of northern highbush blueberry varieties grown in pot and raised-bed

Growing Location	Cultivars	Yield (g/bush)	Berry weight (g)	Firmness (N)	Berry diameter (mm)**
Pot	Bluecrop	921.84 ± 54.08 a*	1.43 ± 0.06 d*	85.00 ± 4.51 a*	13.55 ± 0.23 d*
	Bluegold	918.08 ± 70.94 a	1.75 ± 0.10 c	79.44 ± 2.58 ab	14.83 ± 0.38 d
	Patriot	937.41 ± 87.84 a	2.27 ± 0.18 b	87.29 ± 5.4 a	17.45 ± 0.16 a
	Denise Blue	955.14 ± 55.37 a	2.72 ± 0.18 a	52.45 ± 4.84 c	17.09 ± 0.57 ab
	Brigitta	624.01 ± 24.08 b	2.01 ± 0.07 bc	88.68 ± 4.77 a	16.61 ± 0.26 abc
Raised-bed	Bluecrop	276.62 ± 41.48 c	1.14 ± 0.04 d	85.64 ± 2.46 a	13.53 ± 0.23 d
	Bluegold	178.87 ± 34.57 c	1.22 ± 0.04 d	71.98 ± 4.41 b	13.67 ± 0.33 d
	Patriot	243.42 ± 55.43 c	1.32 ± 0.09 d	85.71 ± 2.39 a	14.33 ± 0.33 de
	Denise Blue	649.15 ± 43.18 b	2.17 ± 0.02 b	71.61 ± 3.68 b	15.96 ± 0.07 c
	Brigitta	299.14 ± 34.28 c	2.05 ± 0.04 bc	70.9 ± 4.59 b	16.33 ± 0.33 bc

**There is no statistical difference at p<0.05 level between the means indicated with the same letter in the columns.*

***Measured using the size scale developed by Banados (2008).*

***± values are standard deviation values**, n=15*

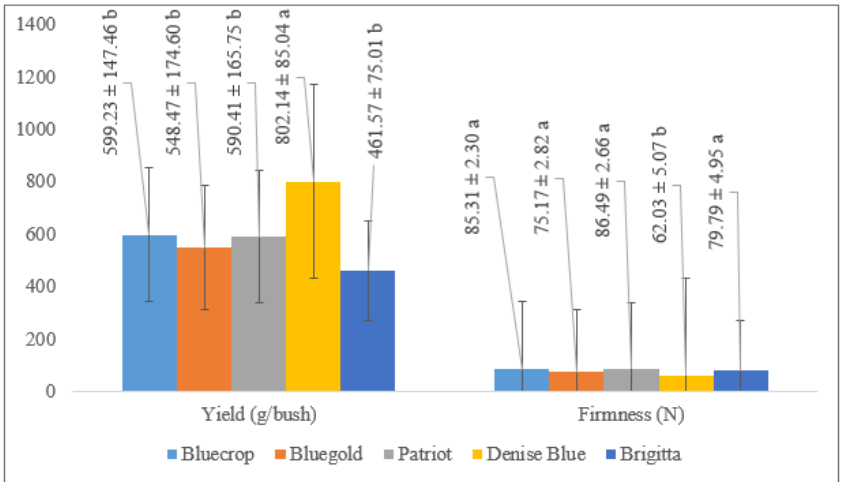

Figure 1. Yield (g/bush) and berry firmness (N) of blueberry varieties grown in raised-bed and pot (± values are standard deviation values, n=15)

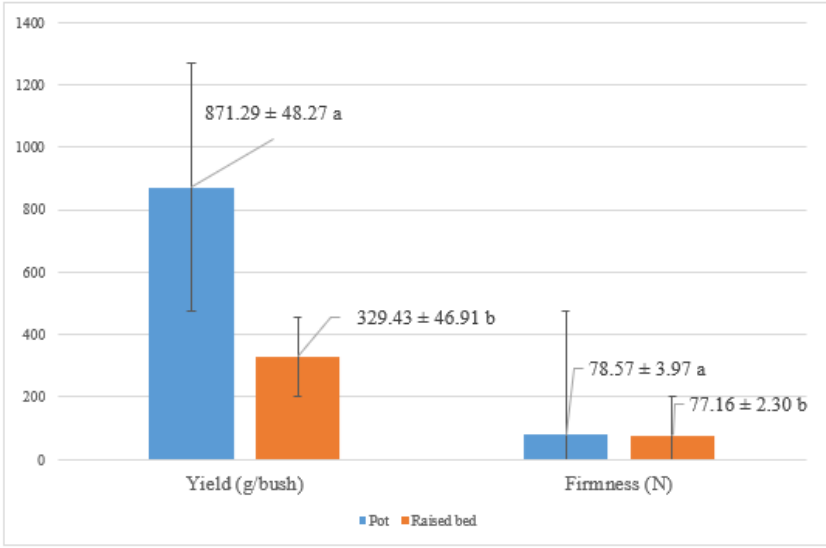

Figure 2. Yield and berry firmness for pot and raised-bed growing blueberries (± values are standard deviation values, n=15)

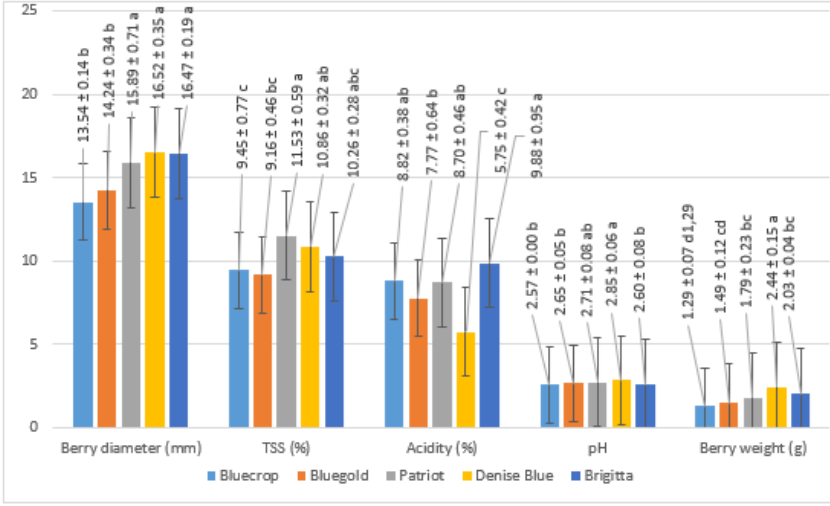

Figure 3. Berry diameter (mm), TSS (%) , acidity (%), pH and berry weight (g) in blueberry varieties grown in raised-bed and pot (± values are standard deviation values, n=15)

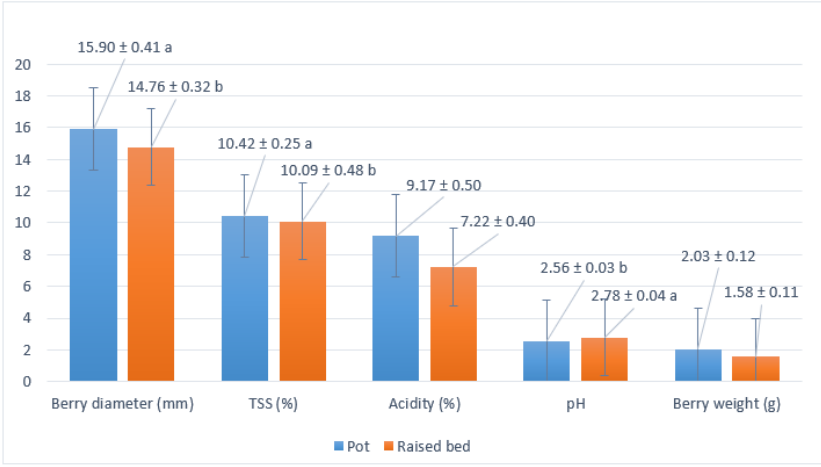

Figure 4. Berry weight (g), pH, acidity (%), TSS (%) and berry diameter (mm) in blueberry varieties according to raised-bed and pot (± values are standard deviation values, n=15)

According to the studies, berry weight, firmness and berry diameter may vary depending on blueberry varieties, growing environments and technical and cultural processes (Çelik, 2018; Çelik and Acar, 2021). All varieties were classified as medium-large berry diameter according to the Banados (2008) circle. In fact, it is reported that fruit diameter may differ according to varieties (Zee et al., 2006) and may also vary according to region, environment and management conditions. Çelik et al. (2020) reported that the fruit diameter of organically grown blueberries ranged between 14.22-20.43 mm and the fruit weight ranged between 1.76-4.22 g. Sterne et al. (2012) observed that 'Patriot' had the largest fruit size with a diameter of 15.00-16.00 mm in Lithuanian conditions. Our findings also resembled to this. Suzuki et al. (1998) found that there were correlative relationships between fruit weight and seed number, flowering and harvest dates, and growth period length in 'Bluecrop' and 'Northland' blueberry varieties grown in greenhouses and pot. When all these are taken into consideration, the diameter determining the berry size in blueberries may vary according to variety, region, ecological and soil conditions. There are significant differences in the size of blueberry fruits among both highbush and rabbiteye varieties (Gündüz et al., 2015). Researchers who stated that large fruits are collected cheaper and preferred by consumers have also determined that large fruits receive higher scores from the panels. Therefore, large fruits are much more suitable for fresh consumption.

In the present study, berry firmness changes between 88.68 N (pot grown Brigitta) and 52.45 N (pot grown Denise Blue) (Table 2). On the other hand, potted

blueberry bushes showed a little bit higher firmness than raised bed ones (Fig. 2). This means that blueberry firmness could be affected by cultivars and growing environment. This affection also determined by Ehlenfeldt and Martin (2002) and NeSmith (2004 and 2006). Ehlenfeldt and Martin (2002) noted that berry hardness may vary according to harvest date, year and stage of ripeness of the berry (green, pink, purple, blue). The researchers also stated that there were significant differences in berry firmness among 87 blueberry cultivars and firmness values ranged from 80.40 ('Herbert') to 189.00 ('Pearl River') (Ehlenfeldt and Martin, 2002). According to the researchers, more than 50% of blueberries offered for fresh consumption are harvested by hand, and the firmness of the fruits is economically very important. We believe that hard-fleshed berry fruits like blueberry, can be easily harvested by machine. Firm fruits may also be kept on the bushes for a long time. Silva et al. (2005) stated that blueberry fruits need to be hard in order to be sent to distant markets. It was determined that the fruit firmness of the 'Bluecrop' variety was the lowest with 254 N compared to 'Climax' (565 N), 'Premier' (406 N), 'Tifblue' (475 N) and 'Jersey' (326 N). In our study pot or raised bed grown 'Bluecrop2 variety showed lower hardness than Silva et al. (2005) findings. This may be affected by environment and growing substrates. Lopez et al. (2010) also stated that the firmness of blueberry fruits will decrease as the temperature increases. Retamales and Hancock (2018), indicate that the quality of blueberries is determined by the size, color, dry matter content, pH and acidity values of the fruit, as well as tasting tests conducted with tasting panels, and they stated that in quality standards, the berry firmness should be more than 70 g/mm and its color should be blue. Firmness is important in blueberries and determines consumer preference, attraction and post-harvest deterioration in fruits. Fruits with high hardness are more durable during harvest and remain intact for a longer time in transportation, and hard fruits can be kept on the plant for a longer time (Retamales and Hancock, 2018, Saftner et al., 2008)

3.3. TSS, Acidity and pH

In the presented study, the TSS, acidity and pH contents of blueberry varieties grown in pot and raised-bed varied according to the growing condition and varieties (Table 3, Figures 3 and 4). While the 'Patriot' variety grown in raised-bed had the highest TSS value with 12.43%, the 'Bluecrop' variety in the same group had the lowest TSS value with 8.27%, followed by the 'Bluegold' variety with 8.47% (Table 3). However, when the growing condition is taken into consideration, the TSS value of blueberry varieties grown in pot was higher than the varieties grown in raised-bed with 10.42% (Figure 4). The %TSS values of the 'Bluecrop' (8.27%) and 'Bluegold' (8.47%) varieties grown in raised beds remained at the lowest level (Table 3). The %TSS content of blueberries is important in terms of taste (Çelik, 2012; Çelik and Ağaoğlu, 2013). This situation was also stated by Yang et al. (2009), and the researchers determined that the 'Bluecrop' variety had the lowest dry matter value with 12.3%. In addition, Saftner et al. (2008) stated that harvest maturity and plant

habitus were also effective on coloration and fruit content (TSS, acidity, pH and firmness) in blueberries and they determined that the amount of fruit dry matter was more flexible in fully developed blueberries. Çelik, (2009) reported that the yield per plant in blueberries varied between 455.21 g. ('Berkeley') and 2567.80 g. ('Ivanhoe') and it was determined that the TSS amount was between 10.04% ('Northland') and 11.01% ('Jersey') with the altitude also affecting this. On the other hand, Pinto et al. (2017) determined that the pot size, growing place and the media used in the pot affected the TSS and fruit diameter. Retamales and Hancock (2018), indicated that the quality of blueberries is determined by the size, color, dry matte, pH and acidity values of the fruit as well as taste conducted with the panelist. They also state that the dry matter should be greater than ten points in quality standards. When the varieties used in the experiment are taken into consideration, we can say that 'Patriot', 'Denise Blue' and 'Brigitta' are above this value and the other varieties are almost close to this limit. On the other hand, it can be said that the higher dry matter amounts of blueberry varieties grown in raised-bed than those grown in pot are again due to sunny hours, temperature and direction. Researchers stated that the dry matter content in blueberries can vary depending on the species, season, location and year, and they found that dry matter value is much more stable than acidity or firmness. (Gündüz et al., 2015; Retamales and Hancock, 2018). It is difficult to obtain fruits with the TSS content desired by consumers in blueberries because there is no sugar accumulation in the harvested blueberries (Retamales and Hancock, 2018). According to Saftner et al. (2008), the TSS values of the 'Bluecrop' and 'Bluegold' varieties were 11.5% and 13.2%. Hancock et al. (2008) found that the TSS values of highbush blueberry varieties ranged from 9.5% ('Bluecrop') to 12.7% ('Brigitta'). This proves that the TSS % value may vary depending on variety, region, ecology, altitude and temperature.

Table 3. Berry properties of northern highbush blueberry varieties grown different growing area

Growing Area	Cultivars	TSS (%)	Acidity (%)	pH
Pot	Bluecrop	10.63 ± 0.47 ab*	9.10 ± 0.60 b	2.56 ± 0.50 c
	Bluegold	9.87 ± 0.30 bc	9.00 ± 0.30 b	2.53 ± 0.01 c
	Patriot	10.63 ± 0.96 ab	9.30 ± 0.40 b	2.55 ± 0.05 c
	Denise Blue	11.3 ± 0.31 ab	6.36 ± 0.43 cd	2.74 ± 0.05 b
	Brigitta	9.67 ± 0.22 bc	11.96 ± 0.38 a	2.43 ± 0.02 c
Raised-bed	Bluecrop	8.27 ± 1.19 c	8.53 ± 0.53 b	2.57 ± 0.03 c
	Bluegold	8.47 ± 0.70 c	6.53 ± 0.65 cd	2.76 ± 0.01 b
	Patriot	12.43 ± 0.12 a	8.10 ± 0.72 b	2.86 ± 0.07 ab
	Denise Blue	10.43 ± 0.49 b	5.13 ± 0.56 d	2.94 ± 0.07 a
	Brigitta	10.87 ± 0.09 ab	7.80 ± 0.00 bc	2.76 ± 0.02 b

**There is no statistical difference at p<0.05 level between the means indicated with the same letter in the columns. ± values are standard deviation values.*

The acidity taken into account in terms of TSS-acid values, known as sweetness-sourness in blueberries, is expressed as citric acid (%). Acidity values, such as dry matter content of blueberry varieties, can also be affected by many factors such as variety, ecology, harvest time, pruning, irrigation and fertilization (Çelik, 2012; Çelik and Ağaoğlu, 2013; Trehane, 2004). Because in addition to varieties, plant nutrition management practices also have important effects on the fruit quality traits of blueberry (Wilber and Williamson, 2008; Bolanos-Alcantara et al., 2019). In our study, acidity vary by cultivars like other studies (Çelik, 2009a; Çelik 2009b). Retamales and Hancock (2018), state that acidity in terms of citric acid should be between 0.3-1.3% in quality standards. In this respect, the acidity values of the blueberries in the trial were higher. This situation was due to ecology and especially sun exposure. In addition, Gündüz et al. (2015) said that organic acids could be determine the taste in highbush blueberries, and they change from year to year and location. Variety and harvest date, sun exposure and growth-development factors in the plant can also affect acidity (Saftner et al. 2008, Retamales and Hancock, 2018).

The 'Brigitta' variety grown in pot was found to have the highest acidity value with 11.96%, while the 'Denise Blue' variety grown in raised-bed was found to have the lowest acidity value with 5.13%. The acidity value of blueberry varieties also varied according to the growing location, and it was found that blueberry varieties grown in pot were more acidic, with the 'Brigitta' variety having the highest acidity value of 9.88%, while the 'Denise Blue' variety had the lowest acidity value of 5.75%. According to Saftner et al. (2008), the acidity values of the 'Bluecrop' and 'Bluegold' varieties were 0.46% and 0.64%, respectively. Our findings are higher than these and this proved that growing conditions, sunny days, pot and/or raised bed and substrates may affect the TSS ratio. Ateş and Çelik (2016) found that the TSS% in some northern highbush blueberry varieties varied between 7.00-14.67.

In terms of pH value, the 'Denise Blue' variety grown in raised-bed had the highest pH value with 2.94, while the 'Brigitta' variety grown in pot had the lowest pH value with 2.43. The pH value, which varies according to the varieties, was found to be the highest in the 'Denise Blue' variety with 2.85 and the lowest in the 'Bluecrop' variety with 2.57. Stringer et al. (2010), who compared the characteristics of the 'Prince' rabbiteye blueberry variety with the 'Brightwell' and 'Climax' varieties, also determined that this variety gave a pH of 3.27. Retamales and Hancock (2018) state that the pH should be between 2.25-4.25 in quality standards. Researchers who say that the pH value of blueberry fruits is related to eating quality and taste indicate that light, temperature, nutrients and water are also effective on fruit quality. Pertuzatti et al. (2016) stated that the pH value in blueberry varieties was different in both the whole fruit and fruit pulp, and determined that the pH was between 2.87 and 3.57 depending on the variety. Our results obtained from these studies are similar in terms of many criteria. Although there are significant differences

between the cultivation type and blueberry varieties in terms of flowering, yield, berry weight, dry matter, acidity and pH. It is known that all these factors are also affected by climatic conditions (Baptista et al. 2006; Ciordia et al. 2002; NeSmith, 2006). Our findings regarding fruit quality criteria were similar to some studies in many respects. Studies have reported that especially fruit quality criteria show significant differences according to varieties (Ciordia et al. 2002; Çelik, 2020).

4. CONCLUSIONS

In the present study, five different northern highbush blueberry varieties were grown outdoors and in peat in both pot and raised-bed, fertilized with slow-released-fertilizers and irrigated with drip irrigation to reveal their growth, development, yield and quality characteristics in Samsun ecological conditions. According to the results, the flower bud bursting of raised-bed grown blueberry varieties occurred at almost the same period as the varieties grown in pot and at the end of February. The leaf buds of pot grown blueberries started later than those grown in raised-bed. On the other hand, flowering in blueberry grown in raised-bed started earlier than in pot grown ones. It was determined that veraison started much earlier in blueberry varieties grown in raised-bed than in pot grown ones. The time of the first harvest and harvest period in blueberry grown in pot and raised-bed differed to the varieties. The harvest in raised-bed grown blueberries was much earlier than in pot and started in the second week of June and continued until the first weeks of August. On the other hand, the harvest of blueberry varieties grown in pot started at the end of June and continued until the end of August, and the harvest periods were longer than those in raised-bed. Similarly, it was determined that the dates of full bloom, fruit set, veraison and formation of blue color in fruits occurred earlier in blueberry varieties grown in raised-bed than in pot. On the other hand, it was determined that TSS, acidity and pH value of fruits were better for some varieties in raised-bed and for others in pot. The increase in demand for blueberries has led to an increase in demand for new, technological and intensive production systems. Intensive cultivation of blueberries in open areas or even in the ground can pose a high risk in terms of fruit production and quality depending on climatic factors. This situation is also affected by the fact that acidic soils are not very common. For this reason, in regions that do not have suitable soil for blueberries but have ecological advantages, the substrates used for blueberry cultivation in pot and/or raised-bed are gaining importance as they will determine various physiological responses that will bring differences in yield and quality.

According to these results, it was revealed that blueberry can be grown in pot using acidified peat in areas where soil pH value is limiting. In raised-bed with adjusted acidity, it was determined that high pH conditions in the soil due to infiltration can negatively affect pH values and this had the negative effects on growth, de-

velopment and yield. In order to bring the harvest time earlier, new studies should be conducted on the possibilities of putting blueberry grown in pot under cover, and on the direction, color and shade ratios of shading material and laying and/or removal periods of covers in order to extend the harvest period to a longer period.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics

This study does not require ethics committee approval.

Author Contribution Rates

Design of Study: HÇ (75%), EA (25%)

Data Acquisition: HÇ (30%), EA (70%)

Data Analysis: HÇ (70%), EA (30%)

Writing up: HÇ (100%)

Submission and Revision: HÇ (100%)

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