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Effects of Different Growing Media and Humic Acid Doses on Plant Growth and Quality in Radish

Farklı Yetiştirme Ortamları ve Hümik Asit Dozlarının Turpta Bitki Gelişimi ve Kalite Üzerine Etkileri

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Abstract: This research was conducted to determine the effects of different growing media and humic acid doses on plant growth parameters and quality properties in cherry-red radish. In the study, 4 different growing media [Soil, Peat:Perlite (1:1), Peat:Perlite (2:1) and Peat:Perlite (3:1)] consisting of soil and mixtures of peat and perlite at different ratios were used. In addition to, 0 (control), 500, 1000 and 2000 ppm doses of humic acid in liquid form named TKİ Hümas were investigated. Rolex F1 cherry-red radish variety (*Raphanus sativus* L. var. *sativus*) was used in the study. According to the findings obtained from the research, it was detected that Peat:Perlite (2:1) medium came to the forefront in terms of plant growth parameters and quality properties among the growing media. It was found that humic acid applications (500, 1000 and 2000 ppm) significantly increased tuber fresh weight, tuber diameter and tuber length compared to the control (0 ppm). Among the humic acid doses, the highest tuber fresh weight, tuber diameter and tuber length were obtained from 1000 ppm dose. In general, it was determined that soilless growing media and humic acid had positive effects on plant growth and quality. When the growing media and humic acid doses are evaluated among themselves, it was concluded that especially Peat:Perlite (2:1) medium and 1000 ppm dose were more effective on plant growth and quality and could be used successfully in soilless cherry-red radish cultivation in terms of agricultural sustainability and productivity.

Keywords: Cherry-red radish, humic substances, growing medium, growth, quality

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Öz: Bu araştırma, fındık turpunda farklı yetiştirme ortamları ve hümik asit dozlarının bitki gelişim parametreleri ve kalite özellikleri üzerine etkilerini belirlemek amacıyla yapılmıştır. Çalışmada toprak ile torf ve perlit ortamlarının farklı oranlardaki karışımlarından oluşan 4 farklı yetiştirme ortamı [Toprak, Torf:Perlit (1:1), Torf:Perlit (2:1) ve Torf:Perlit (3:1)] kullanılmıştır. Çalışmada ayrıca TKİ Hümas isimli sıvı formda hümik asidin 0 (kontrol), 500, 1000 ve 2000 ppm dozları ele alınmıştır. Çalışmada Rolex F1 fındık turpu çeşidi (*Raphanus sativus* L. var. *sativus*) kullanılmıştır. Araştırmadan elde edilen bulgulara göre yetiştirme ortamları arasında bitki gelişim parametreleri ve kalite özellikleri yönünden Torf:Perlit (2:1) ortamının öne çıktığı tespit edilmiştir. Çalışmada hümik asit uygulamalarının (500, 1000 ve 2000 ppm) yumru yaş ağırlığı, yumru çapı ve yumru yüksekliğini kontrole (0 ppm) göre önemli oranda artırdığı saptanmıştır. Hümik asit dozları arasında en yüksek yumru yaş ağırlığı, yumru çapı ve yumru yüksekliği 1000 ppm dozundan elde edilmiştir. Genel olarak topraksız yetiştirme ortamları ve hümik asidin bitki gelişimi ve kalite üzerinde olumlu etkilerinin olduğu belirlenmiştir. Yetiştirme ortamları ve hümik asit dozları kendi aralarında değerlendirildiğinde, özellikle Torf:Perlit (2:1) yetiştirme ortamının ve 1000 ppm dozunun bitki gelişimi ve kalite üzerinde daha etkili olduğu ve topraksız fındık turpu yetiştiriciliğinde tarımsal sürdürülebilirlik ve verimlilik açısından başarılı bir şekilde kullanılabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Fındık turpu, hümik maddeler, yetiştirme ortamı, büyüme, kalite

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INTRODUCTION

Radish (*Raphanus sativus* L.), which is widely grown and consumed all over the world, is a cool climate vegetable belonging to the Brassicaceae (Cruciferae) family. It is a popular salad vegetable grown in tropical, subtropical, and temperate regions. The consumed root part of radish can be of various sizes and colors. Radish genotypes with small and red roots are called as cherry-red radish (Vural et al., 2000). Radish is generally consumed raw in garnishes and salads, but in some countries, it is also consumed cooked, pickled, or dried. Radish, which has an important place in human nutrition, is rich in A, B and C vitamins, minerals such as calcium, phosphorus, potassium and iron, and antioxidant substances (Akan et al., 2013). Radish is also of great importance in terms of human health (Chung et al., 2012). It is reported that radish can be evaluated as a functional food due to the compounds it contains and its contribution to human health (Akan et al., 2013). Soil properties have a great effect on the formation of quality roots in radish. Generally, radish grows better in deep, organic matter-rich, permeable, light-textured, loamy and sandy-loam soils. In heavy soils, deformations and cracks occur in the roots of radish (Solmaz and Sarı, 2013).

Radish is grown widely and year-round in Turkey. Radish cultivation in our country is especially concentrated in the Mediterranean, Aegean and Central Anatolia Region (Solmaz et al., 2017). In Turkey, radish was grown in an area of 57.228 da with a production of 188.662 tons in 2022 (TÜİK, 2023).

It is reported that 75.6% of Türkiye's agricultural lands are insufficient in terms of organic matter (Eyüpoğlu, 1998). In addition, because of intensive and unconscious chemical fertilization, the amount of organic matter in the soil and thus the humus ratio decreases rapidly. Therefore, the use of organic matter in agriculture is becoming increasingly important.

One of the fastest, economical and effortless solutions to the organic matter problem in plant production is the application of humic substances to the soil or plant. Humic substances are naturally occurring, chemically stable, high molecular weight, in colors ranging from yellow to black, resistant to degradation, heterogeneous and complex organic molecules (Mac Carthy, 2001). Humic substances play a significant role in agriculture and have important effects on plant growth and development (Nardi et al., 2002). Humic substances are divided into three groups as humic acid, fulvic acid and humin according to their solubility properties (Sparks, 2003).

Humic acids are black or dark brown substances formed by partially or completely decomposed plant or animal residues (Bandiera et al., 2009; Fan et al., 2015). Humic acids can be found in varying concentrations in natural resources such as peat, leonardite, hard coal, animal manure, compost, sewage sludge and lignite (Akıncı, 2011). In today's agriculture, humic acids play an increasingly active role. It improves the soil structure physically, chemically and biologically, provides aeration of the soil, increases the permeability, fertility and water holding capacity of the soil, reduces the evaporation of water in the soil, regulates the soil pH, increases the microorganism activities in the soil, increases the amount of organic matter in the soil, facilitates the uptake of plant nutrients in the soil by plants and increases the availability of nutrients (Türkmen et al., 2004; Tüfenkçi et al., 2006; Gürsoy et al., 2016). In addition, humic acid is known to increase resistance to many diseases, pests and stress conditions (Demirtaş et al., 2014). It can be an important supportive for plants in the struggle stress factors that reduce crop productivity such as drought and salinity, and in reducing the toxic effects of heavy metals (Masciandaro et al., 2002; Nardi et al., 2002; Akıncı, 2011). Humic acid increases seed germination, plant growth, flowering, yield and quality. Humic acid helps to protect the environment as well as contributing to the economy by increasing the effectiveness of chemical fertilizers and preventing excessive use of fertilizers (Gezgin et al., 2012). It can be used safely in organic agriculture because it does not contain chemicals and is obtained from natural sources. Thus, with the use of humic acid, both plant growth is supported, and human health is protected. Commercially produced humic acids are in powder or liquid form and can be applied to the seed, soil or plant. It is applied to plants by spraying and to the soil as a solution (Obsuwan et al., 2011).

In the studies carried out in different vegetable species, it has been determined that humic acid has significant effects on plant growth, yield and quality (Kazemi, 2014; Uğur et al., 2014; Yılmaz, 2014; Köse, 2015; Mirdad, 2016; Uğur et al., 2016a; Baş Odabaş, 2019; Özdemir, 2019). However, there is a need for adequate studies on how much the most appropriate dose should be for different types of vegetables.

Humic acids are also widely used in greenhouses in plant production. Excessive use of chemical fertilizers in greenhouses has led to salinity, desertification, soil fatigue and reductions in soil organic matter content. In addition, due to the continuous cultivation of the same species in greenhouses, there is an increase in disease factors and nematodes in the soil. As a result of this, soilless farming techniques have been developed to eliminate soil-related problems, to be able to cultivate in places where the soil is not suitable for vegetative production, and to increase the yield and crop quality in the unit area. Soilless agriculture is divided into two groups as water culture (hydroponic) and solid medium culture (substrate, aggregate). The substrates used are classified in three main groups as organic (peat, cocopeat, bark, sawdust, rice husk, hazelnut husk, peanut shell, etc.), inorganic (perlite, vermiculite, rock wool, sand, gravel, volcanic tuff, pumice, slag, zeolite, etc.) and synthetic (polyurethane foam) (Leonardi, 2004; Gül, 2008). These growing media are used alone or mixed with each other in certain proportions. Researchers have determined that the effects of different growing media on different plants are different (Gül et al., 2003; Polat et al., 2017). Peat and perlite are growing media that are abundant in our country (Sevgican, 2003).

The aim of this study was to investigate the effects of different growing media and humic acid doses on plant growth parameters and quality properties in cherry-red radish.

MATERIAL AND METHOD

The study was carried out in the climate room and laboratory of Bolu Abant İzzet Baysal University, Faculty of Agriculture, Department of Horticulture in 2020.

Material

Rolex F1 cherry-red radish variety (*Raphanus sativus* L. var. *sativus*) was used in the study. Soil and mixtures of peat and perlite in different ratios were used as the growing medium in the research. The soil taken from Bolu Abant İzzet Baysal University Faculty of Agriculture Application Area land was used as soil material in the experiment. Some physical and chemical properties of soil used in the study are given in Table 1. Peat (Emin) and perlite (Hölpower) used in the study were purchased from the market. Humic acid in liquid form named TKİ Hümas, originating from leonardite produced by Turkish Coal Enterprises Institution (TKİ) was used as humic acid material. Humic acid used in the study has 5% total organic matter, 12% total humic + fulvic acid, 3% water soluble potassium oxide and 11-13 pH content. Ammonium sulfate and triple super phosphate commercial fertilizers were also used in the study.

Method

Preparation of the Growing Media and Experimental Design

In the study, 4 different growing media [Soil (Control), Peat:Perlite (1:1), Peat:Perlite (2:1) and Peat:Perlite (3:1)] consisting of soil and mixtures of peat and perlite at different ratios (v/v) were used. To grow plants, plastic pots (60 x 18 x 16 cm) were used. Each pot was filled with 14 liters of growing medium and placed on shelfs in the climate room. The experiment was established in completely randomized design with 3 replications. In the study, 48 pots (4 growing media x 4 humic acid doses x 3 replicates) were used.

Seed Sowing, Humic Acid Applications, Cultivation of Plants and Harvesting

The experiment was carried out in a climate room with an ambient temperature of 20±1 ° C, a humidity of 50-55%, and a 13-hour light/11-hour dark period. Seed sowing was done on 12.10.2020. Seed sowing was carried at a depth of 1.5-2 cm and in two rows to pots. Irrigation was performed immediately after sowing the seeds. The first emergences were detected 3-6 days after sowing. After 10 days of emergence, thinning was done by leaving approximately 15 plants in each pot.

In the study, 0 (control), 500, 1000 and 2000 ppm doses of humic acid were used. Humic acid solutions prepared at the doses examined in the experiment were applied homogeneously from the soil on the 5th and 15th days after sowing. Ammonium sulfate and triple super phosphate commercial fertilizers were applied with the calculation of 10 kg N da^{-1} and 8 kg P_2O_5 da^{-1}, respectively. All of phosphorus fertilizer and half of the nitrogen fertilizer were given with seed sowing, and the other half of the nitrogen fertilizer was applied 2 weeks after sowing.

All necessary cultural practices were performed regularly during cultivation period (Vural et al., 2000). The plants were harvested 45 days after sowing on 27.11.2020. Necessary measurements and analyzes of the harvested plants were made in the laboratory of Bolu Abant Izzet Baysal University, Faculty of Agriculture, Department of Horticulture. Some photos of the study are demonstrated in Figure 1.

Table 1. Some physical and chemical properties of soil used in the study.
Çizelge 1. Çalışmada kullanılan toprağın bazı fiziksel ve kimyasal özellikleri.

Examined properties	Determined Values
Texture	Clay
Sand (%)	18.50
Silt (%)	24.00
Clay (%)	57.50
pH	7.28
Lime (%)	32.50
EC (dS/m)	0.63
Organic matter (%)	1.46
Available potassium (K_2O, kg/da)	54.90
Available phosphorus (P_2O_5, kg/da)	6.30

Measurements and Analyses Made in the Plants

Measurements of morphological properties were made on 15 plants for each application. All analyses were performed with three replications.

In the study, 24 properties related to plant growth and quality were examined. Plant height (cm), petiole length (cm), leaf blade length (cm), leaf blade width (cm) and root tail length (cm) were determined by measuring with a ruler. Petiole thickness (mm), tuber diameter (mm) and tuber length (mm) were measured with a digital caliper. Leaf fresh weight (g) and tuber fresh weight (g) were determined by weighing with a precision balance. Leaf dry weight (g) and tuber dry weight (g) were detected by weighing with a precision balance the samples after drying in an oven at 65 °C until they reach a constant weight. The number of leaves (number plant^{-1}) was determined by counting the leaves on the plant. The dry matter contents in tuber and leaf (%) were detected by using the procedures of AOAC (1990). The chlorophyll content of the leaves (spad) was determined with a chlorophyll meter (Apogee Chlorophyll Concentration Meter, MC-100). The color properties of tubers (L*, a*, b*, Chroma and Hue angle) were detected using a colorimeter (3NH NR60CP). The pH values of the tuber samples were measured using a digital pH meter (Thermo Scientific, Orion Star A111). Total soluble solid content of tubers (%) was measured with a hand-held refractometer (ATC-1, Atago, Japan). Tuber firmness (kg cm^{-2}) was determined by penetrometer.

Statistical Analysis

The data obtained in the study were subjected to variance analysis using the JMP 13.2 statistical program. Statistical differences among the means found to be significant in terms of the examined properties were determined by Tukey's Honestly Significant Difference (HSD) multiple comparison test.

Figure 1. Some photos of the study.
Şekil 1. Çalışmaya ait bazı fotoğraflar.

RESULTS AND DISCUSSION

The analysis of variance showed that the difference among the growing media in terms of number of leaves, leaf fresh weight, leaf dry weight and petiole length was statistically significant (P<0.01). On the other hand, no statistically significant difference was found among the growing media in terms of plant height, petiole thickness, leaf blade length and leaf blade width. There were significant differences (P<0.05) in terms of leaf fresh weight and petiole length among the humic acid doses. However, there was no statistically significant difference among the humic acid doses with respect to plant height, number of leaves, leaf dry weight, petiole thickness, leaf blade length and leaf blade width. When the interaction between growing medium and humic acid dose was examined, it was found to be significant in terms of all the examined properties except petiole thickness (Table 2).

In the present study, plant height varied between 14.29 and 18.58 cm. The highest values regarding plant height were found in Soil+1000 ppm and Peat:Perlite (2:1)+0 ppm applications, while the lowest plant height was observed in Soil+0 ppm application. Among the growing media, the highest value in terms of number of leaves was determined in Peat:Perlite (2:1) medium (6.58), whereas the lowest values were observed in other growing media which were statistically in the same group. The number of leaves varied from 5.67 [Peat:Perlite (3:1)+500 ppm] to 6.92 [Peat:Perlite (2:1)+0 ppm] depending on growing medium × humic acid dose interaction. When growing media were examined, the highest values in terms of leaf fresh weight and leaf dry weight was found in Peat:Perlite (2:1) medium (9.02 and 0.86 g, respectively). However, the lowest leaf fresh and dry weight were observed in Peat:Perlite (1:1) medium (7.70 and 0.65 g, respectively). Among the humic acid doses, the highest leaf fresh weight was determined in 0 ppm (control) with 8.94 g, though the lowest leaf fresh weight was detected in 500 and 2000 ppm doses which there was no statistically significant difference between them. Compared to the control (0 ppm), the lower values in terms of leaf fresh weight were obtained from humic acid applications. Depending on different growing media and humic acid doses discussed in the study, the leaf fresh and dry weight values in cherry-red radish varied from 6.65 to 10.61 g and 0.59 to 1.16 g, respectively. Among the growing media, maximum petiole length was found in Peat:Perlite (3:1) medium (6.78 cm), whereas minimum petiole length values were observed in other growing media which were statistically in the same group. When humic acid doses were examined, the highest petiole length was determined in 0 ppm (control) with 6.55 cm. However, the lowest petiole length was detected in 2000 ppm (5.47 cm). Regarding growing medium × humic acid dose interaction, it was found that the highest petiole length (9.17 cm) was detected in Peat:Perlite (3:1)+0 ppm application, while the lowest petiole length (4.21 cm) was observed in Peat:Perlite (3:1)+2000 ppm application. Leaf blade length and width in cherry-red radish ranged from 9.83 to 11.58 cm and 5.17 to 6.92 cm, respectively, depending on growing medium × humic acid dose interaction.

Güler (2011) reported that plant height and plant fresh weight in curly lettuce varied depending on different growing media (rock wool, perlite, zeolite, grape marc, and soil). Researcher also stated that there was no significant difference among different growing media in terms of number of leaves. In studies conducted on different vegetable species, the effect of humic acid on plant height and number of leaves was found to be statistically insignificant (Uğur et al., 2014; Yılmaz, 2014; Uğur et al., 2016a, 2016b; Kibar, 2022), which was agreed with the findings in this study. However, Bhuvaneswari and Dhanasekaran (2007) and Barzegar et al. (2021) reported that humic acid applications in radish significantly increased number of leaves compared to the control. In a study conducted on sorrel, petiole length, leaf blade length and leaf blade width varied depending on different growing media (peat, perlite, cocopeat and hazelnut husk) (Sezer, 2015). In the study conducted by Kocamanoğlu (2018) on purslane, it was determined that the shoot length and shoot diameter values significantly changed depending on different growing media and humic acid doses. Similar to the results obtained in this study, Ondrasek et al. (2018) stated that there was no significant difference between humic acid treatments and control in terms of leaf dry weight in radish. The effect of humic acid applications on leaf length and leaf width was found to be statistically insignificant in studies conducted on chard and lettuce (Uğur et al., 2014; Uğur et al., 2016b; Özdemir, 2019), which was compatible with our findings. Contrary to our results, in previous studies conducted on different vegetable species, it was determined that humic acid applications significantly increased plant height, number of leaves, plant fresh weight, plant dry weight, leaf length and petiole length compared to the control (Köse, 2015; Uğur et al., 2016a, b; Baş Odabaş, 2019; Özdemir, 2019; Jan et al., 2020; Obaid et al., 2020; Kibar, 2022).

Table 2. Effects of different growing media and humic acid doses on plant height, number of leaves, leaf fresh weight, leaf dry weight, petiole length, petiole thickness, leaf blade length and leaf blade width in cherry-red radish.
Çizelge 2. Farklı yetiştirme ortamları ve hümik asit dozlarının fındık turpunda bitki boyu, yaprak sayısı, yaprak yaş ağırlığı, yaprak kuru ağırlığı, yaprak sapı uzunluğu, yaprak sapı kalınlığı, yaprak ayası uzunluğu ve yaprak ayası genişliği üzerine etkileri.

Properties	Growing media	Humic acid doses (ppm)				
		0	500	1000	2000	Mean
Plant height (cm)	Soil	14.29c**	15.96abc	18.58a	16.92abc	**16.44^NS^**
	Peat:Perlite (1:1)	15.33abc	16.25abc	16.33abc	18.00ab	**16.48**
	Peat:Perlite (2:1)	18.50a	17.08abc	17.17abc	17.25abc	**17.50**
	Peat:Perlite (3:1)	17.67abc	17.38abc	16.67abc	14.71bc	**16.60**
	Mean	**16.45^NS^**	**16.67**	**17.19**	**16.72**	
Number of leaves (number plant^{-1})	Soil	5.92bc**	5.75c	6.00abc	5.75c	**5.85B****
	Peat:Perlite (1:1)	6.08abc	6.25abc	6.25abc	6.00abc	**6.15B**
	Peat:Perlite (2:1)	6.92a	6.75ab	6.75ab	5.92bc	**6.58A**
	Peat:Perlite (3:1)	5.83bc	5.67c	5.83bc	6.00abc	**5.83B**
	Mean	**6.19^NS^**	**6.10**	**6.21**	**5.92**	
Leaf fresh weight (g)	Soil	7.91bc**	7.18bc	9.14ab	7.90bc	**8.03AB****
	Peat:Perlite (1:1)	6.65c	8.02bc	7.75bc	8.38abc	**7.70B**
	Peat:Perlite (2:1)	10.61a	7.98bc	9.10ab	8.38abc	**9.02A**
	Peat:Perlite (3:1)	10.59a	8.59abc	7.57bc	7.18bc	**8.48AB**
	Mean	**8.94A***	**7.94B**	**8.39AB**	**7.96B**	
Leaf dry weight (g)	Soil	0.68cde**	0.79bc	0.65cde	0.74cde	**0.71B****
	Peat:Perlite (1:1)	0.60de	0.66cde	0.67cde	0.69cde	**0.65B**
	Peat:Perlite (2:1)	1.16a	0.90b	0.68cde	0.71cde	**0.86A**
	Peat:Perlite (3:1)	0.76bcd	0.60de	0.68cde	0.59e	**0.66B**
	Mean	**0.80^NS^**	**0.74**	**0.67**	**0.68**	
Petiole length (cm)	Soil	5.63cd**	5.04cd	6.21bc	5.88cd	**5.69B****
	Peat:Perlite (1:1)	5.58cd	6.13bc	5.33cd	6.33bc	**5.84B**
	Peat:Perlite (2:1)	5.83cd	5.46cd	6.29bc	5.46cd	**5.76B**
	Peat:Perlite (3:1)	9.17a	7.83ab	5.92cd	4.21d	**6.78A**
	Mean	**6.55A***	**6.11AB**	**5.94AB**	**5.47B**	
Petiole thickness (mm)	Soil	2.46^ns^	2.42	2.29	2.39	**2.39^NS^**
	Peat:Perlite (1:1)	2.22	2.19	2.51	2.55	**2.37**
	Peat:Perlite (2:1)	2.30	2.43	2.32	2.14	**2.30**
	Peat:Perlite (3:1)	2.20	2.38	2.47	2.38	**2.36**
	Mean	**2.29^NS^**	**2.35**	**2.40**	**2.36**	
Leaf blade length (cm)	Soil	10.38ab*	10.88ab	10.71ab	10.63ab	**10.65^NS^**
	Peat:Perlite (1:1)	10.25ab	9.96ab	10.21ab	11.58a	**10.50**
	Peat:Perlite (2:1)	10.88ab	10.38ab	10.96ab	9.83b	**10.51**
	Peat:Perlite (3:1)	10.79ab	10.08ab	10.33ab	10.17ab	**10.34**
	Mean	**10.57^NS^**	**10.32**	**10.55**	**10.55**	
Leaf blade width (cm)	Soil	5.71ab*	5.71ab	5.17b	5.33ab	**5.48^NS^**
	Peat:Perlite (1:1)	5.42ab	5.33ab	6.92a	6.38ab	**6.01**
	Peat:Perlite (2:1)	5.29b	5.92ab	6.17ab	5.42ab	**5.70**
	Peat:Perlite (3:1)	5.79ab	5.71ab	5.96ab	5.88ab	**5.84**
	Mean	**5.55^NS^**	**5.67**	**6.05**	**5.75**	

*: Significant at P < 0.05, **: Significant at P < 0.01, ns: non-significant. Means followed by different letters are statistically different according to Tukey's honestly significant difference test.

As seen in Table 3, the difference among the growing media in terms of tuber fresh weight, tuber dry weight, tuber diameter, tuber length, root tail length and total soluble solid content was significant at the $P<0.01$ level, while the difference among the growing media in terms of tuber firmness was significant at the $P<0.05$ level. On the other hand, no statistically significant difference was found among the growing media in terms of pH values. There were significant differences in terms of tuber fresh weight ($P<0.01$), tuber length ($P<0.01$), tuber diameter ($P<0.05$) and tuber firmness ($P<0.05$) among the humic acid doses. However, there was no statistically significant difference among the humic acid doses with respect to tuber dry weight, root tail length, pH and total soluble solid content. The interaction between growing medium and humic acid dose was found to be significant ($P<0.01$) in terms of all the examined properties.

When the effect of different growing media on tuber fresh weight, which is the most important yield parameter, is examined, Peat:Perlite (2:1) medium had the highest value with 19.44 g, while the lowest tuber fresh weight was determined in Peat:Perlite (3:1) medium with 11.47 g. Among the humic acid doses, the highest tuber fresh weight was determined in 1000 and 2000 ppm doses (16.67 and 16.27 g, respectively), which there was no statistically significant difference between them. However, the lowest tuber fresh weight was observed in 0 ppm (control) with 13.56 g. It was determined that humic acid had a positive effect on tuber fresh weight. In general, tuber fresh weight values increased with the increase in humic acid dose. In the present study, tuber fresh weight differed significantly according to different growing media and humic acid doses. Tuber fresh weight values varied between 8.31 and 20.55 g. With respect to tuber fresh weight, Peat:Perlite (2:1)+1000 ppm application took the first place, and it was closely followed by Peat:Perlite (2:1)+2000 ppm, Peat:Perlite (2:1)+500 ppm and Peat:Perlite (2:1)+0 ppm applications. However, the lowest tuber fresh weight was observed in Peat:Perlite (3:1)+0 ppm application. In parallel with tuber fresh weight, the highest tuber dry weight was also obtained from Peat:Perlite (2:1) medium with 1.00 g, though the lowest tuber dry weight was determined in Peat:Perlite (3:1) medium with 0.60 g. Depending on different growing media and humic acid doses discussed in the study, tuber dry weight values in cherry-red radish varied from 0.40 to 1.01 g. Among the growing media, the highest tuber diameter and tuber length values were found in Peat:Perlite (2:1) medium (34.41 and 36.66 mm, respectively), whereas the lowest values were observed in Peat:Perlite (3:1) medium (23.69 and 26.63 mm, respectively). When humic acid doses were examined, the highest values in terms of tuber diameter and tuber length were obtained from 1000, 500 and 2000 ppm doses, which were not statistically different. In contrast, control plants (0 ppm) not treated with humic acid were found to have the lowest tuber diameter and tuber length. In the study, it was determined that humic acid significantly increased tuber diameter and tuber length compared to the control (0 ppm). Depending on different growing media and humic acid doses discussed in the study, tuber diameter and tuber length values varied from 21.15 to 37.67 mm and 24.53 to 39.62 mm, respectively. The highest tuber diameter and tuber length values were obtained from Peat:Perlite (2:1)+500 ppm application, whereas the lowest values observed in Peat:Perlite (3:1)+0 ppm application. Among the growing media, the highest root tail length was determined in Soil and Peat:Perlite (2:1) media, which were not statistically different. On the contrary, the lowest root tail length values were observed in Peat:Perlite (3:1) and Peat:Perlite (1:1) media. Root tail length values in cherry-red radish varied from 4.58 to 9.17 cm depending on growing medium × humic acid dose interaction. When growing media were examined in terms of tuber firmness, Peat:Perlite (3:1) medium (5.35 kg cm^{-2}) took the first place, and it was closely followed by Peat:Perlite (2:1) and Peat:Perlite (1:1) media. However, the lowest tuber firmness was observed in Soil medium (3.73 kg cm^{-2}). It was found that soilless growing media had higher tuber firmness values compared to the soil medium. Tuber firmness increased with the increase of peat ratio in the growing medium. Among the humic acid doses, the highest tuber firmness was recorded in 0 ppm dose (control) with 5.39 kg cm^{-2}, and 500 and 1000 ppm doses followed closely it. On the other hand, the lowest tuber firmness was detected in 2000 ppm dose (3.94 kg cm^{-2}). In terms of tuber firmness, lower values were obtained from humic acid applications compared to the control (0 ppm). Tuber firmness values decreased with the increase of humic acid dose. Tuber firmness varied from 3.33 to 7.27 kg cm^{-2} depending on growing medium × humic acid dose interaction. In the present study, pH values in cherry-red radish varied from 6.02 to 6.66. Peat:Perlite (1:1)+1000 ppm application possessed the highest pH value, though the lowest pH value was detected in Peat:Perlite (2:1)+1000 ppm application. Among the growing media, maximum total soluble solid content was found in Soil, Peat:Perlite (1:1) and Peat:Perlite (2:1) media (2.81, 2.74 and 2.52%, respectively), which were not statistically different, whereas minimum total soluble solid content was recorded in Peat:Perlite (3:1) medium (2.06%). In terms of total soluble solid content, lower values were obtained from the soilless growing media compared to the Soil medium. As the peat ratio increased in the growing medium, the total soluble solid content decreased. When growing medium × humic acid dose interaction was examined, total soluble solid content ranged from 1.83 [Peat:Perlite (3:1)+500 ppm] to 3.33% [Peat:Perlite (1:1)+0 ppm].

Table 3. Effects of different growing media and humic acid doses on tuber fresh weight, tuber dry weight, tuber diameter, tuber length, root tail length, tuber firmness, pH and total soluble solid content in cherry-red radish.
Çizelge 3. Farklı yetiştirme ortamları ve hümik asit dozlarının fındık turpunda yumru yaş ağırlığı, yumru kuru ağırlığı, yumru çapı, yumru uzunluğu, kuyruk uzunluğu, yumru sertliği, pH ve suda çözünebilir kuru madde miktarı üzerine etkileri.

Properties	Growing media	Humic acid doses (ppm)				
		0	500	1000	2000	Mean
Tuber fresh weight (g)	Soil	13.31c-g**	18.11abc	16.76a-e	12.47efg	**15.16B****
	Peat:Perlite (1:1)	13.58c-f	15.43b-e	16.41a-e	17.92a-d	**15.84B**
	Peat:Perlite (2:1)	19.03ab	19.05ab	20.55a	19.14ab	**19.44A**
	Peat:Perlite (3:1)	8.31g	9.06fg	12.96d-g	15.53b-e	**11.47C**
	Mean	**13.56B****	**15.41AB**	**16.67A**	**16.27A**	
Tuber dry weight (g)	Soil	0.74ef**	0.98ab	0.94abc	0.75def	**0.85B****
	Peat:Perlite (1:1)	0.75def	0.81def	0.81def	0.87bcd	**0.81B**
	Peat:Perlite (2:1)	1.00a	1.01a	1.01a	0.97ab	**1.00A**
	Peat:Perlite (3:1)	0.40g	0.47g	0.69f	0.83cde	**0.60C**
	Mean	**0.72^{NS}**	**0.82**	**0.86**	**0.85**	
Tuber diameter (mm)	Soil	28.21d-g**	23.82ghı	27.63efg	25.98fgh	**26.41C****
	Peat:Perlite (1:1)	28.96def	32.31bcd	31.01cde	31.01cde	**30.82B**
	Peat:Perlite (2:1)	28.34d-g	37.67a	36.33ab	35.28abc	**34.41A**
	Peat:Perlite (3:1)	21.15ı	25.64f-ı	25.03f-ı	22.96hı	**23.69D**
	Mean	**26.66B***	**29.86A**	**30.00A**	**28.81AB**	
Tuber length (mm)	Soil	28.60def**	31.05b-e	29.30def	30.39c-f	**29.84C****
	Peat:Perlite (1:1)	29.30def	33.66a-d	35.60abc	34.24a-d	**33.20B**
	Peat:Perlite (2:1)	30.53c-f	39.62a	39.26a	37.23ab	**36.66A**
	Peat:Perlite (3:1)	24.53f	27.00ef	29.48c-f	25.49ef	**26.63D**
	Mean	**28.24B****	**32.83A**	**33.41A**	**31.84A**	
Root tail length (cm)	Soil	7.79a-d**	9.17a	7.88a-d	7.50a-d	**8.08A****
	Peat:Perlite (1:1)	5.79de	6.00cde	6.13b-e	5.13e	**5.76B**
	Peat:Perlite (2:1)	8.21ab	8.17ab	8.00abc	7.96abc	**8.08A**
	Peat:Perlite (3:1)	4.75e	4.58e	4.88e	6.21b-e	**5.10B**
	Mean	**6.63^{NS}**	**6.98**	**6.72**	**6.70**	
Tuber firmness (kg/cm^2)	Soil	3.33b**	3.63b	4.35ab	3.58b	**3.73B***
	Peat:Perlite (1:1)	5.38ab	5.20ab	4.83ab	3.78b	**4.80AB**
	Peat:Perlite (2:1)	5.58ab	6.57ab	4.62ab	3.34b	**5.03AB**
	Peat:Perlite (3:1)	7.27a	3.85b	5.23ab	5.05ab	**5.35A**
	Mean	**5.39A***	**4.81AB**	**4.76AB**	**3.94B**	
pH	Soil	6.37a-e**	6.41a-d	6.44a-d	6.48abc	**6.43^{NS}**
	Peat:Perlite (1:1)	6.25b-f	6.15def	6.66a	6.19c-f	**6.31**
	Peat:Perlite (2:1)	6.06ef	6.40a-d	6.02f	6.55ab	**6.26**
	Peat:Perlite (3:1)	6.35a-e	6.51ab	6.26b-f	6.29b-f	**6.35**
	Mean	**6.26^{NS}**	**6.37**	**6.35**	**6.38**	
Total soluble solid content (%)	Soil	2.67b-e**	2.80bc	3.00ab	2.77bcd	**2.81A****
	Peat:Perlite (1:1)	3.33a	2.40def	2.37ef	2.87bc	**2.74A**
	Peat:Perlite (2:1)	3.03ab	2.57cde	2.37ef	2.10fg	**2.52A**
	Peat:Perlite (3:1)	1.87g	1.83g	2.17fg	2.37ef	**2.06B**
	Mean	**2.73^{NS}**	**2.40**	**2.48**	**2.53**	

*: Significant at $P < 0.05$, **: Significant at $P < 0.01$, ns: non-significant. Means followed by different letters are statistically different according to Tukey's honestly significant difference test.

In the study conducted by Kocamanoğlu (2018) on purslane, it was determined that yield and shoot diameter values changed depending on different growing media. Researcher also stated that yield and shoot diameter values in humic acid applications were higher than the control, and the yield and shoot diameter increased with the increase of the humic acid dose. Similar to our findings, Güllüce et al. (2012) and Barzegar et al. (2021) reported that humic acid treatments in radish significantly increased tuber fresh weight, tuber diameter and tuber length compared to the control. Ondrasek et al. (2018) stated that tuber dry weight in radish varied between 0.82-0.97 g and there was no significant difference between humic acid applications and control in terms of tuber dry weight, which was consistent with our findings. Güler (2011) reported that head diameter of curly lettuce varied depending on different growing media (rock wool, perlite, zeolite, grape marc, and soil). Bhuvaneswari and Dhanasekaran (2007) reported that higher values were obtained from humic acid applications compared to the control in terms of root length in radish. Kibar (2022) stated that there was no statistically significant difference between control and humic acid treatments in terms of root length in lettuce. In contrast to our results, Barzegar et al. (2021) detected that humic acid applications in radish significantly increased tuber firmness compared to the control. Toprak and Gül (2013) reported that there was no significant difference among growing media in terms of pH and total soluble solid content in tomato. The effect of humic acid applications on pH value in tomato was found to be statistically insignificant (Yıldırım, 2007; Öktüren Asri et al., 2016), which was compatible with our results. Similar to our findings, in studies conducted on different vegetables, it was found that humic acid did not have a significant effect on total soluble solid content (Demirtaş et al., 2014; Yılmaz, 2014; Kibar, 2022). On the other hand, Barzegar et al. (2021) determined that humic acid applications in radish significantly increased total soluble solid content compared to the control.

The effect of growing media on dry matter content in tuber and a* color value was significant at the $P<0.05$ level, and the effect of growing media on dry matter content in leaf and L* color value was significant at the $P<0.01$ level. On the other hand, no statistically significant difference was found among the growing media in terms of chlorophyll content, b*, Chroma and Hue angle color values. While the difference among the humic acid doses was statistically significant ($P<0.05$) only in terms of dry matter content in tuber, the effect of humic acid doses on other properties examined was found to be insignificant. The interaction between growing medium and humic acid dose was found to be significant in terms of all the examined properties except b* color value (Table 4).

Among the growing media, maximum value for dry matter content in tuber was determined in Soil medium (5.41%), whereas minimum value was recorded in Peat:Perlite (2:1) medium (4.56%). When the effect of different humic acid doses on dry matter content in tuber was examined, 0 ppm (control) took the first place with 5.32% and 1000 ppm dose followed closely it. On the other hand, 500 and 2000 ppm doses had the lowest dry matter content in tuber values with 4.68 and 4.71%, respectively. The highest value with regard to dry matter content in leaf was found in Peat:Perlite (2:1) medium (6.97%), while the lowest value was observed in Peat:Perlite (3:1) medium (5.79%). Dry matter content in tuber and leaf varied from 3.98 [Peat:Perlite (2:1)+2000 ppm] to 6.52 [Peat:Perlite (1:1)+0 ppm] and 4.92 [Soil+0 ppm] to 7.58% [Soil+500 ppm], respectively, depending on growing medium × humic acid dose interaction. In the present study, chlorophyll content ranged from 40.83 [Peat:Perlite (3:1)+0 ppm] to 47.24 spad [Peat:Perlite (3:1)+1000 ppm]. When the effect of growing media on color properties of cherry-red radish was examined, the highest L* values were found in Peat:Perlite mixtures (1:1, 2:1 and 3:1), though the lowest value was detected in Soil medium. Peat:Perlite (3:1) medium possessed the highest a* value (28.94). On the other hand, the lowest a* value (26.24) was observed in Peat:Perlite (2:1) medium. In the study, and apparent effect of humic acid doses on color properties of cherry-red radish was not observed. The color properties of cherry-red radish tubers (except for b* value**)** considerably changed depending on growing medium × humic acid dose interaction. The L*, a*, b*, Chroma and Hue angle values ranged from 35.46 to 40.20, 24.33 to 30.32, 10.03 to 11.91, 26.12 to 32.48 and 19.56 to 23.43, respectively.

Table 4. Effects of different growing media and humic acid doses on dry matter content in tuber, dry matter content in leaf, chlorophyll content, color properties in tuber (L*, a*, b*, Chroma and Hue angle) in cherry-red radish.

Çizelge 4. Farklı yetiştirme ortamları ve hümik asit dozlarının fındık turpunda yumruda kuru madde miktarı, yaprakta kuru madde miktarı, klorofil içeriği ve yumruda renk özellikleri (L, a*, b*, Kroma ve Hue açısı) üzerine etkileri.*

Properties	Growing media	Humic acid doses (ppm)				
		0	500	1000	2000	Mean
Dry matter content in tuber (%)	Soil	5.58ab**	5.06b-e	5.53abc	5.47a-d	**5.41A***
	Peat:Perlite (1:1)	6.52a	4.49b-e	4.75b-e	4.51b-e	**5.07AB**
	Peat:Perlite (2:1)	4.74b-e	4.80b-e	4.72b-e	3.98e	**4.56B**
	Peat:Perlite (3:1)	4.46cde	4.37de	5.54abc	4.89b-e	**4.81AB**
	Mean	**5.32A***	**4.68B**	**5.14AB**	**4.71B**	
Dry matter content in leaf (%)	Soil	4.92d**	7.58a	6.72abc	5.78bcd	**6.25AB****
	Peat:Perlite (1:1)	6.76abc	6.54a-d	6.06a-d	6.19a-d	**6.39AB**
	Peat:Perlite (2:1)	7.09ab	6.54a-d	7.51a	6.75abc	**6.97A**
	Peat:Perlite (3:1)	5.48bcd	5.33cd	5.70bcd	6.65abc	**5.79B**
	Mean	**6.06NS**	**6.50**	**6.50**	**6.34**	
Chlorophyll content (spad)	Soil	42.33bc*	43.44abc	41.61bc	42.34bc	**42.43NS**
	Peat:Perlite (1:1)	43.43abc	45.80ab	41.73bc	42.74bc	**43.43**
	Peat:Perlite (2:1)	45.79ab	47.17a	42.70bc	42.72bc	**44.59**
	Peat:Perlite (3:1)	40.83c	41.14bc	47.24a	42.72bc	**42.99**
	Mean	**43.10NS**	**44.39**	**43.32**	**42.63**	
L*	Soil	35.74bc**	38.66abc	35.73bc	35.46c	**36.40B****
	Peat:Perlite (1:1)	38.24abc	39.10abc	39.17abc	36.82abc	**38.33A**
	Peat:Perlite (2:1)	35.68bc	38.33abc	38.88abc	40.20a	**38.27A**
	Peat:Perlite (3:1)	39.62ab	37.05abc	38.19abc	37.97abc	**38.21A**
	Mean	**37.32NS**	**38.29**	**38.00**	**37.61**	
a*	Soil	29.36ab**	25.13bc	28.64abc	27.91abc	**27.76AB***
	Peat:Perlite (1:1)	29.57ab	26.72bc	25.83bc	29.03ab	**27.79AB**
	Peat:Perlite (2:1)	28.82abc	26.64bc	24.33c	25.14bc	**26.24B**
	Peat:Perlite (3:1)	27.38abc	30.23a	27.83abc	30.32a	**28.94A**
	Mean	**28.78NS**	**27.18**	**26.66**	**28.10**	
b*	Soil	11.91ns	10.85	11.31	11.55	**11.40NS**
	Peat:Perlite (1:1)	10.49	10.41	10.03	11.56	**10.62**
	Peat:Perlite (2:1)	11.40	11.02	10.07	10.62	**10.78**
	Peat:Perlite (3:1)	10.77	11.78	10.33	11.34	**11.05**
	Mean	**11.14NS**	**11.01**	**10.43**	**11.27**	
Chroma	Soil	31.69ab**	27.39ab	30.80ab	30.21ab	**30.02NS**
	Peat:Perlite (1:1)	31.38ab	28.70ab	27.69ab	31.29ab	**29.76**
	Peat:Perlite (2:1)	31.01ab	28.85ab	26.12b	27.33ab	**28.33**
	Peat:Perlite (3:1)	28.88ab	32.48a	29.71ab	32.40a	**30.87**
	Mean	**30.74NS**	**29.35**	**28.58**	**30.31**	
Hue angle	Soil	22.16ab*	23.43a	21.59ab	22.44ab	**22.40NS**
	Peat:Perlite (1:1)	19.56b	21.57ab	21.31ab	21.88ab	**21.08**
	Peat:Perlite (2:1)	21.69ab	22.61ab	22.59ab	23.06ab	**22.49**
	Peat:Perlite (3:1)	22.24ab	21.31ab	20.39ab	20.76ab	**21.18**
	Mean	**21.41NS**	**22.23**	**21.47**	**22.04**	

*: Significant at $P < 0.05$, **: Significant at $P < 0.01$, ns: non-significant. Means followed by different letters are statistically different according to Tukey's honestly significant difference test.

Toprak and Gül (2013) reported that there was no significant difference among growing media in terms of dry matter amount in tomato. In a study conducted in sorrel, it was found that the dry matter content values in the leaf changed according to the growing medium (Sezer, 2015), which was compatible with the results of this study. Ondrasek et al. (2018) stated that dry matter amount in tuber of radish varied between 4.0-4.4% and that humic acid treatment did not cause a significant effect on dry matter amount in the tuber. Similar to the results of this study, it was reported that there was no significant difference between control and humic acid applications in terms of leaf dry matter ratio in lettuce (Uğur et al., 2014; Kibar, 2022) and radish (Ondrasek et al., 2018). Barzegar et al. (2021) reported that there was no significant difference between control and humic acid treatments in terms of chlorophyll content in radish, which was consistent with our findings. Likewise, it was determined that the effect of humic acid treatments on chlorophyll content in different vegetables was statistically insignificant (Ozdamar Unlu et al., 2011; Uğur et al., 2014; Özdemir, 2019; Kibar, 2022). However, it was detected that humic acid applications in different vegetable species significantly increased chlorophyll content compared to the control (Kazemi, 2014; Mirdad, 2016; Özdemir, 2019; Tunçtürk et al., 2020). Sezer (2015) reported that leaf Chroma and Hue angle color values in sorrel varied depending on the growing media. In the study conducted by Kocamanoğlu (2018) on purslane, it was stated that leaf Chroma values changed depending on growing medium and growing medium does not affect leaf Hue angle values. Researcher also reported that the effect of humic acid treatments on Chroma and Hue angle color values is statistically insignificant. In previous studies conducted on different vegetable species, it was found that differences between control and humic acid applications were found to be statistically insignificant in terms of L*, a*, b*, Chroma and Hue angle color values (Öktüren Asri et al., 2016; Uğur et al., 2016a, b; Kibar, 2022), which was agreed with the findings of our study.

CONCLUSION

In recent years, humic acid applications have become increasingly important in terms of sustainability of soil fertility in plant production, increasing plant development, yield and quality, reducing the risk of environmental pollution and being used in organic agriculture. In this study, the effects of different growing media and humic acil doses on plant growth parameters and quality properties of cherry-red radish were examined.

Among the growing media, the highest values in terms of the number of leaves, leaf fresh weight, leaf dry weight, tuber fresh weight, tuber dry weight, tuber diameter, tuber length, root tail length and dry matter content in leaf were determined in Peat:Perlite (2:1) medium. Peat:Perlite (2:1) medium increased number of leaves by 12.48%, tuber fresh weight by 28.23%, tuber dry weight by 17.65%, tuber diameter by 30.29% and tuber length by 22.86% compared to the Soil medium. When compared to the Soil medium, soilless growing media were found to have higher petiole length, tuber firmness and L* color values. However, lower results in terms of total soluble solid content and dry matter content in tuber were obtained from soilless growing media in comparison with Soil medium. As the peat ratio increased in the growing medium, tuber firmness increased, and total soluble solid content decreased.

In the study, it was determined that humic acid applications (500, 1000 and 2000 ppm) significantly increased tuber fresh weight, tuber diameter and tuber length in comparison with the control (0 ppm). Among the humic acid doses, the highest tuber fresh weight, tuber diameter and tuber length were obtained from 1000 ppm dose. It was found that 1000 ppm humic acid dose increased the tuber fresh weight, tuber diameter and tuber length by 22.94, 12.53 and 18.31%, respectively, compared to the control (0 ppm). On the other hand, lower values were obtained from humic acid applications compared to the control in terms of leaf fresh weight, dry matter content in tuber, petiole length and tuber firmness. As the humic acid dose increased, tuber firmness and petiole length decreased. In the present study, an apparent effect of humic acid doses on color properties of cherry-red radish was not observed.

When growing medium × humic acid dose interaction was examined, it was detected that tuber fresh weight, tuber diameter and tuber length values varied from 8.31 to 20.55 g, 21.15 to 37.67 mm and 24.53 to 39.62 mm, respectively. In the study, tuber fresh weight varied significantly depending on different growing media and humic acid doses. The highest tuber fresh weight was found in Peat:Perlite (2:1)+1000 ppm application, while the lowest tuber fresh weight was observed in Peat:Perlite (3:1)+0 ppm application.

Consequently, it was determined that soilless growing media and humic acid generally had positive effects on plant growth parameters and quality properties. It was concluded that Peat:Perlite (2:1) medium among the growing media and 1000 ppm dose among the humic acid doses could be recommended to increase plant growth and quality in cherry-red radish.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DECLARATION OF AUTHOR CONTRIBUTION

YÖÖ: Carrying out of the experiment, performing of laboratory studies. BK: Design of the study, statistical analysis, writing of the manuscript.

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