Research Article

www.dergipark.org.tr/en/pub/mediterranean

MEDITERRANEAN AGRICULTURAL SCIENCES
(2024) 37(3): 155-164
DOI: 10.29136/mediterranean.1455528

Determination of water-retention and physicochemical properties of selected media as related to tomato seedling quality parameters

Erdem YILMAZ, Emine Ruya NAMAL

Akdeniz University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, 07756, Türkiye

Corresponding author: E. Yilmaz, e-mail: erdemyilmaz@akdeniz.edu.tr
Author(s) e-mail: ruyanamal@gmail.com

ARTICLE INFO

Received: March 21, 2024
Received in revised form: November 12, 2024
Accepted: November 13, 2024

***Keywords*:**

Diatomite
Growing medium
Peat
Vermicompost
Zeolite

ABSTRACT

In this study, it was aimed to determine the relationships between changes in water retention properties and some physicochemical properties of different growth media used in seedling cultivation and tomato (*Solanum lycopersicon* cv.) seedling quality parameters. Growing media were prepared from eight different mixtures of peat (P), diatomite (D), zeolite (Z) and vermicompost (V). KAYRA F1 tomato variety was used for the seedling. At the end of 45 days of incubation, the water retention characteristics of medias were determined at different matric potential (0, -2, -4, -5, -8, -10, -33 and -1500 kPa). The highest available water capacity was realized in M1 (100% peat) and the highest saturation value was realized in M5 (70% peat + 15% zeolite + 15% vermicompost). Nutrient content and chemical and physical properties of the media were important for tomato seedling yield and quality parameters. Especially the increase in the ratio of vermicompost with a high EC value in the mixture caused a decrease in the germination rate. In the mixtures with a vermicompost ratio not exceeding 15%, significant improvement was achieved in seedling quality parameters. The best medium for tomato seedling yield and the quality parameters were obtained in M8 (70% peat + 10% zeolite + 10% diatomite + 10% vermicompost), and it was also observed that favorable results may be obtained in terms of quality seedling cultivation in M6 (70% peat + 15% diatomite + 15% vermicompost), M5 (70% peat + 15% zeolite + 15% vermicompost) and M4 (80% peat + 20% vermicompost) mediums.

1. Introduction

The most important factors affecting the success of soilless agriculture are ecology, greenhouse structure, climate, growing system planning, seedling type, variety and growing environment. The world population is expected to reach 9.7 billion in 2050 and 11 billion by 2100 (United Nations 2021). Novel and improved agricultural systems should be introduced in urban areas due to limited arable land, soil degradation and water scarcity (Lehman et al. 1993). In vegetables grown in the field and under greenhouse conditions, ready-made seedlings are generally used as starting material in production. While ready-to-use seedling production companies in Türkiye produce aproximately 2 billion seedlings annually, tomato ranks first among the seedlings produced with 41.2% (Yelboğa 2014; Tüzel et al. 2015). The use of ready-made seedlings in Türkiye was 100% in greenhouse agriculture and 70% in field agriculture (Yelboğa 2014). In 2020, the area of greenhouse agriculture in Türkiye was 805159 ha. Among the species grown in greenhouses, tomato ranks first in terms of both area and production. Of the total 7771766 tons of vegetables grown in greenhouses, 4099129 tons are tomatoes, with a share of approximately 52% (TÜİK 2021).

Cultivation carried out in soilless agriculture is divided into two, substrate and hydroponic culture (Gül 2012). Various substrates, both inorganic and organic, can be used as growth media and inorganic substrates include expanded clay, glass wool, gravel, perlite, pumice, rock wool, sand sepiolite, vermiculite, volcanic tuff and zeolite. The organic substrates include bark, coconut coir, coco soil, fleece, marc, peat, ruffia bark, and rice husk, saw dust and wood chips (Mariyappillai and Arumugam 2021). The main objective in crop production is to produce healthy and high-quality products with high yields. The growing medium must meet different criteria such as physical, chemical, hydrological and biological properties to meet the growth requirements of the plant (Nelson 2012). The medium used in soilless media should be cheap and readily available, have good drainage, low volume-to-weight ratio, good rehydration properties after drying, stable structure, good pH-buffering capacity, low micro-organism activity, good aeration, free from diseases and pests, non-toxic, low soluble salt content, and should not lose its chemical and biological properties after sterilization (Sevgican 1999; Gruda et al. 2013). Due to environmental issues, the search for alternative components to remove or reduce peat, traditionally the main component of most seedling growing media, has been the subject of numerous studies in recent years (Abad et al. 2001). In this sense, special attention has been paid to the use of composts, municipal waste and other residual materials of organic origin (Barral et al. 2007; Paradelo et al. 2012, 2016).

The media to be used in seedling cultivation should be an ideal mixture that can meet the demands of vegetables. Prepared seedling media mixtures should be specific to the plant species. For this reason, it is important to determine the ideal media mixtures that can meet the requirements of many vegetables (Uzun 2001; Doğan 2003). It has been reported that the volume of media available for use by tomato plants grown on a soil bed in a greenhouse is about 200 L, whereas the corresponding volume size for production in soilless culture (substrate media) is smaller (Sonneveld 1981).

Many researchers have tested and modeled many properties of materials that can be used as growing media in soilless culture (Pokorny and Henny 1984; Pokorny et al. 1986; Bures et al. 1993a, b). Any media used in soilless culture can have some effect on plant growth, as well as the fertilizers added. In addition, the porosity of the medium and the state of water are also very important for plant growth. The physical and hydraulic properties of most substrates are superior to those of soils. However, the hydraulic properties of substrates used in soilless agriculture have not been adequately characterized to date. In addition, each of the media components used is unique in terms of air/water properties (Raviv and Leith 2008). These definitions are limited to only a few parameters or to limited soil water matric potential (up to -10 kPa) (Wallach et al. 1992). Understanding the water retention characteristics of the growing medium can help develop best management practices for containerized farming systems for efficient management of irrigation water (Kumar et al. 2010).

In this study, it was aimed to a) determine the differences in physicochemical properties and water retention ability of growing media consisting of different mixtures of peat, diatomite, zeolite and vermicompost b) assess differences in tomato seedling quality parameters as a response to different growing media.

2. Material and Methods

Four different materials were used to create diverse growing media: zeolite, peat, diatomite and vermicompost. The materials were obtained from different commercial companies. The Kekkilä brand peat obtained from peat deposits in Finland was used in the study. The main components of the peat are white and brown Sphagnum peat. Vermicompost is an organic fertilizer that is obtained as a result of the processing of food consisting entirely of organic wastes (such as cattle manure, vegetable and fruit wastes, fruit pulp, etc.) by worms in a period of 10-12 months. The zeolite used in the study is a natural soil conditioner called Agro-Clino and is produced from zeolite-clinoptilolite. Diatomite was obtained from AGRIPOWER commercial company. The product, commercially produced under the name Agripower Silica, is a material composed of skeletal remains (diatoms) of freshwater algae (Melosira Granulata species). Some analytical data of the materials declared by the manufacturers are given in Table 1.

The research was conducted in the greenhouses of the Faculty of Agriculture of Akdeniz University (Fig 1). The greenhouse used was a double-span, north and south oriented Venlo-type greenhouse, covered with ethylene-tetra fluoroethylene film, equipped with air conditioning for winter heating, and supported by natural ventilation through the roof and side windows. Experiments were carried out on 4 x 1 m tables inside the greenhouse. Indoor temperature values given in Table 2 were obtained from the greenhouse thermometer.

In the study, KAYRA F1 hybrid (*Solanum lycopersion* cv.) tomato seeds were used as a plant material to determine the effects of different media on seedling development. The tomato variety used is a high-yielding variety suitable for spring and summer planting, with high aroma, long shelf life, tolerant to Fusarium radici (For) and Fusarium 0.1 (L2) and resistant to cracking.

Table 1. Physicochemical properties of substrates used in the preparation of media*

Parameters	Substrates			
	Peat	Vermicompost	Zeolite	Diatomite
Size	-	-	<50mm	<50mm
pH	5.9	7.0	-	-
EC (dS m^{-1})	0.24	3.2	-	-
Organic matter (%)	90	39.96	-	-
Bulk density (g cm^{-3})	0.85	-	0.45-0.55	-
Grain density (g cm^{-3})	-	-	-	1.9-2.1
Porosity (%)	-	-	35-40	35-40
Moisture (%)		30.39	120-125	120-125
SiO_2 (%)	-	-	68.8	-
Al_2O_3 (%)	-	-	14.6	-
Total potassium (K) (mg kg^{-1})	700-1200	9600	-	-
Total phosphorus(P) (mg kg^{-1})	150-450	14000	-	-
Total nitrogen (N) (%)	0.04-0.12	3.2	-	-
Organic nitrogen (N) (%)	-	2.5	-	-
$CaCO_3$ (%)	0.48	-	-	-
C/N	-	8.42	-	-
Total humic + fulvic acid (%)	-	25.07	-	-

*: Values declared by the commercial company.

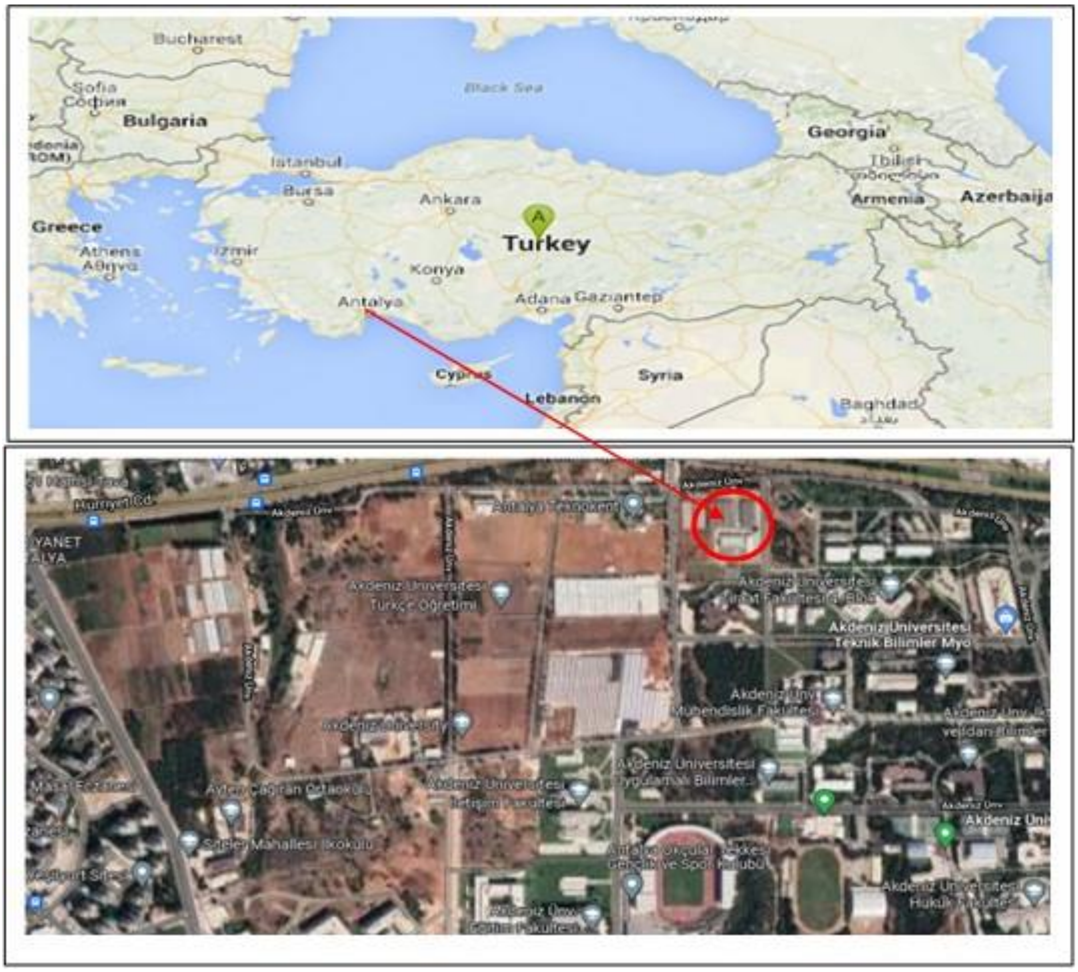


Figure 1. The location of the research area.

Table 2. Temperature values inside the greenhouse during the experiment*

	Trial duration (week)						
Temperature (°C)	1	2	3	4	5	6	7
Min.	14.0	15.4	13.3	11.3	12.4	14.7	14.5
Max.	28.9	31.5	27.6	23.4	28.3	32.3	29.6
Mean	21.5	23.5	20.4	17.4	20.3	23.2	22.1

*: Temperature data are the mean of measurements made four times a day.

The experiment was established according to the randomized plot design and consisted of a total of 40 pots including 8 growing media with 5 replications. The mixtures of growth media given in Table 3 were prepared and placed in 13.5 L pots with dimensions of 15 cm x 57 cm x 17 cm. In each pot, 20 tomato seeds were planted 1 cm below the surface and a total of 800 seedlings were used. No nutrients were added to the media during the experiment and only irrigation was made to each medium according to the plant's requirement. Irrigation was applied to all seedlings in equal amounts, considering the turgor of the seedlings. Some chemical and physical properties of the growing media are given in Table 4.

In the study, the amount of water retained by the medium was determined at matric potential values of 0, -2, -4, -5, -8 and -10 kPa in the Eijkelkamp Sand-Box device. The same samples were then placed in the pressure membrane and the amount of water retained at -33 kPa and -1500 kPa was determined (Demiralay 1993). The total porosity of the media was determined by calculating the volume of water retained at 0 kPa and the macro-pore percentages were determined by calculating the difference between the volume of water retained at 0 kPa and -5 kPa (Demiralay 1993).

The bulk density of the media was determined using the cylinder method (Demiralay 1993), and pH and EC values were determined using a pH and EC meter in a 1:5 mixture of media:water (Jackson 1967). The cation exchange capacity of the media was determined according to 1 N ammonium acetate method (Kacar 1995).

The effects of different growing media on the development of tomato seedlings were evaluated using seedling height (cm), germination percentage (%), stem diameter (mm), root length (cm), fresh root weight (g), fresh stem weight (g). The chlorophyll content of the seedlings was measured 40 days after planting with a portable chlorophyll meter (Minolta SPAD-502, Osaka, Japan). SPAD measurements were carried out by selecting 5 seedlings from each pot and 3 leaves for each seedling in the open air before noon (11:00-12:00). The measurements

Table 3. Growing media prepared using four different substrates

Growing media	Description
1. %100 Peat	M1
2. %80 Peat + %20 Zeolite	M2
3. %80 Peat + %20 Diatomite	M3
4. %80 Peat + % 20 Vermicompost	M4
5. %70 Peat + %15 Zeolite + %15 Vermicompost	M5
6. %70 Peat + %15 Diatomite + %15 Vermicompost	M6
7. %70 Peat + %15 Zeolite + %15 Diatomite	M7
8. %70 Peat + %10 Zeolite + %10 Diatomite + %10 Vermicompost	M8

Table 4. Some measured analytical data of growing media

Growing media	pH (1:5)	EC (µS cm^{-1})	CEC (cmol kg^{-1})	Bulk density (g cm^{-3})
M1	5.67	249	280	0.49
M2	5.60	167	75	0.66
M3	6.99	398	75	0.73
M4	6.66	1623	50	0.56
M5	6.54	967	21	0.64
M6	6.79	1313	215	0.53
M7	6.40	294	190	0.74
M8	6.82	614	165	0.72

were made on the secondary and tertiary leaves after the cotyledon leaves. Each leaf SPAD value obtained was given as the average of 3 readings on each side of the midrib.

Descriptive statistics of mean and standard deviation were calculated, and the ANOVA technique was used to infer the effects of different growing media on tomato seedling variables. The Duncan's mean comparison test was used to group the statistically significant data. The SAS 9.4 program was used in statistical analysis and the differences in the variables P<0.05 were considered statistically significant.

3. Results

The amount of water retained in the growing media at different matric potentials (0, -2, -4, -5, -8, -10, -33 and -1500 kPa) is given in Fig 2. The highest moisture content at saturation point (0 kPa) occurred in M4 with 59.41% and the lowest moisture content in M7 with 44.64%. Except for the highest matric potential value (-1500 kPa), M4 had the highest moisture content of all matric potential values. In addition, when the difference between the moisture contents of the media at 0 kPa (saturation point) and -1500 kPa was examined, the highest moisture content was in M4 (41.54%), and the environments were ranked as M4>M1>M5>M8>M2>M6>M3>M7 in terms of water contents. On the other hand, when the difference between the moisture contents of the media at -33 kPa and -1500 kPa was considered, the media were ranked as M1>M4>M4>M8>M5>M3>M7>M2>M6>M3>M6 from the highest to the lowest moisture content (Fig. 2).

Measurements of some quality parameters of tomato seedlings grown in different growing medium are given in Fig. 3 a–ı. It was determined that all parameters, except the seedling root length (cm), were statistically significant depending on the difference in the growing medium. Differences between germination percentages in different growing medium were found to be statistically significant (P<0.0001) (Fig 3a). The highest germination percentage was obtained in M_1 (79%) medium. M_2 (76%), M_8 (67%), M_3 (63%) and M_7 (59%) mediums took place in the same group in terms of germination percentage. The lowest germination percentage was determined in M_4 (17%) medium.

The changes in stem diameter values of tomato seedlings grown in different growing media are shown in Fig. 3b. The differences between the stem diameter values of tomato seedlings were statistically significant (P<0.0001). The highest stem diameter was obtained in M8 (3.56 mm) and M4 (3.54 mm), while the lowest stem diameter was obtained in M7 (2.35 mm).

The changes in the height of tomato seedlings in different growing media are shown in Fig. 3c. The differences between the seedling heights in the growing media were statistically significant (P<0.0001). The highest seedling height values were obtained in M4 (22.21 cm), M5 (22.12 cm) and M8 (19.5 cm) environments and these environments were statistically in the same group. The lowest seedling height value was obtained in M7 (10.85 cm).

Changes in the root length of tomato seedlings in different growing media are shown in Fig. 3d. The differences between the root lengths of seedlings in different growing media were not statistically significant. The changes in fresh root weight of tomato seedlings in different growing media are shown in Fig. 3e. The differences between fresh root weights were statistically significant (P<0.0001) and the highest fresh root weight was obtained in M8 (19.12 g) and the lowest fresh root weight was obtained in M2 (3.31 g).

Changes in dry root weight of tomato seedlings in different growing media are shown in Fig. 3f. The differences between seedling root dry weights in different growing media were statistically significant (P<0.0001). The highest seedling root dry weights were obtained in M8 (1.32 g) and M5 (1.13 g) and these media were statistically in the same group. The lowest seedling root dry weight value was obtained in M7 (0.42 g).

Changes in tomato seedling fresh weight in different growing media are shown in Fig. 3g. In the study, the differences between seedling fresh weights in different growing environments were found to be statistically significant (P<0.0001). The highest fresh weight value was determined in M8 (144.44 g) and the lowest fresh weight value was determined in M7 (37.14 g).

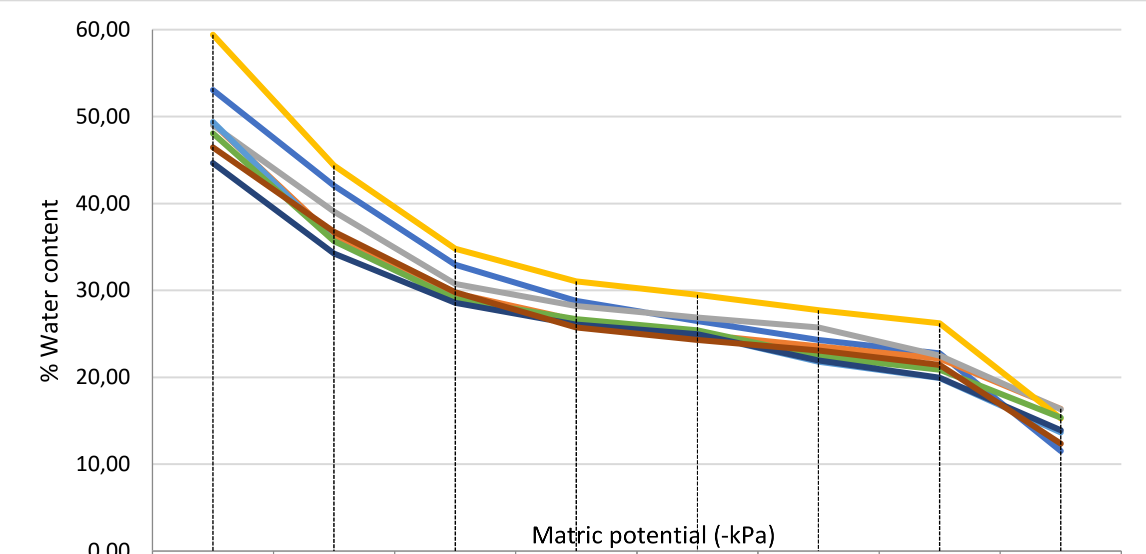
Changes in seedling dry weight of tomato seedlings in different growing media are shown in Fig. 3h. The differences between the dry weights of the seedlings in the growing media were statistically significant (P<0.0001). The highest seedling dry weight was obtained in M8 (15.24 g), while the lowest seedling dry weight was obtained in M7 (3.56 g), M2 (4.04 g), M3 (5.57 g) and M1 (6.09 g).

Changes in leaf chlorophyll content of tomato seedlings in different growing media are shown in Fig. 3i. The differences in leaf chlorophyll content of seedlings in different growing media were found statistically significant (P<0.0001). The highest chlorophyll content was measured in M6 (45.27spad) and the lowest chlorophyll content was measured in M1 (31.47spad).

4. Discussion

The highest amount of water retained at almost all matric potential (except for -1500 kPa) was found in the containing peat + vermicompost (M4). At -1500 kPa (15 atm) the water content stored in M1 media (%11.51) was lower than in the other media. This result implies that, under wilting point conditions, the M1 substrate contains a lower water content than the other media. This effect is due to the fact that the entire medium was composed of peat with a fibrous structure and had the lowest bulk density, thus releasing water easily under the low matric potential. Similar results to ourswere also reported by Fields et al (2004). According to Kutilek and Novak (1998), hydrological properties, such as water retention and water flow rate, are largely dependent on the total porosity and pore size distribution of the medium. However, according to the data obtained in our study, it is understood that chemical properties are as important as physical properties in the effect of growing medium on water properties. As a matter of fact, it was observed that the high EC values of the media with high proportions of vermicompost caused a decrease in their usefulness despite the high amount of water retention in these media. It is also thought that the increase in the osmotic pressure value of the medium with the increase in the EC value plays a role in this effect. In general, it is reported that the pH value for seedling growing media should be slightly acidic, and the EC should be lower than the value considered normal for many plants in the soil (De Boodt and Verdonck 1972). An ideal growth medium must have a pH range between 5.3 and 6.5; and the EC level must be less than 0.50 dS m^{-1} (Raviv et al. 1986; Abad et al. 2001).

On the other hand, under the highest matric potential, M1 had the lowest moisture content, but considering the moisture difference between -33 kPa and -1500 kPa, M1 had the highest moisture content. This is followed by M4 and M8. Physical (fiber content and pore size distribution) and some chemical (cation exchange capacity, electrical conductivity) properties of media



	0	2	4	5	8	10	33	1500
M1	53,05	42,05	32,95	28,79	26,46	24,31	22,75	11,51
M2	49,20	36,12	29,68	26,56	24,96	23,56	22,17	16,36
M3	49,01	39,06	30,73	28,19	26,88	25,73	22,48	16,32
M4	59,41	44,36	34,79	31,05	29,48	27,71	26,21	15,27
M5	49,37	35,67	29,01	26,00	25,00	21,78	19,90	13,65
M6	48,06	35,67	29,01	26,69	25,41	22,41	20,88	15,35
M7	44,64	34,23	28,57	26,05	24,96	21,95	19,93	13,90
M8	46,45	36,75	29,77	25,73	24,31	23,06	21,43	12,36

Figure 2. Water–release characteristic curves growing media.

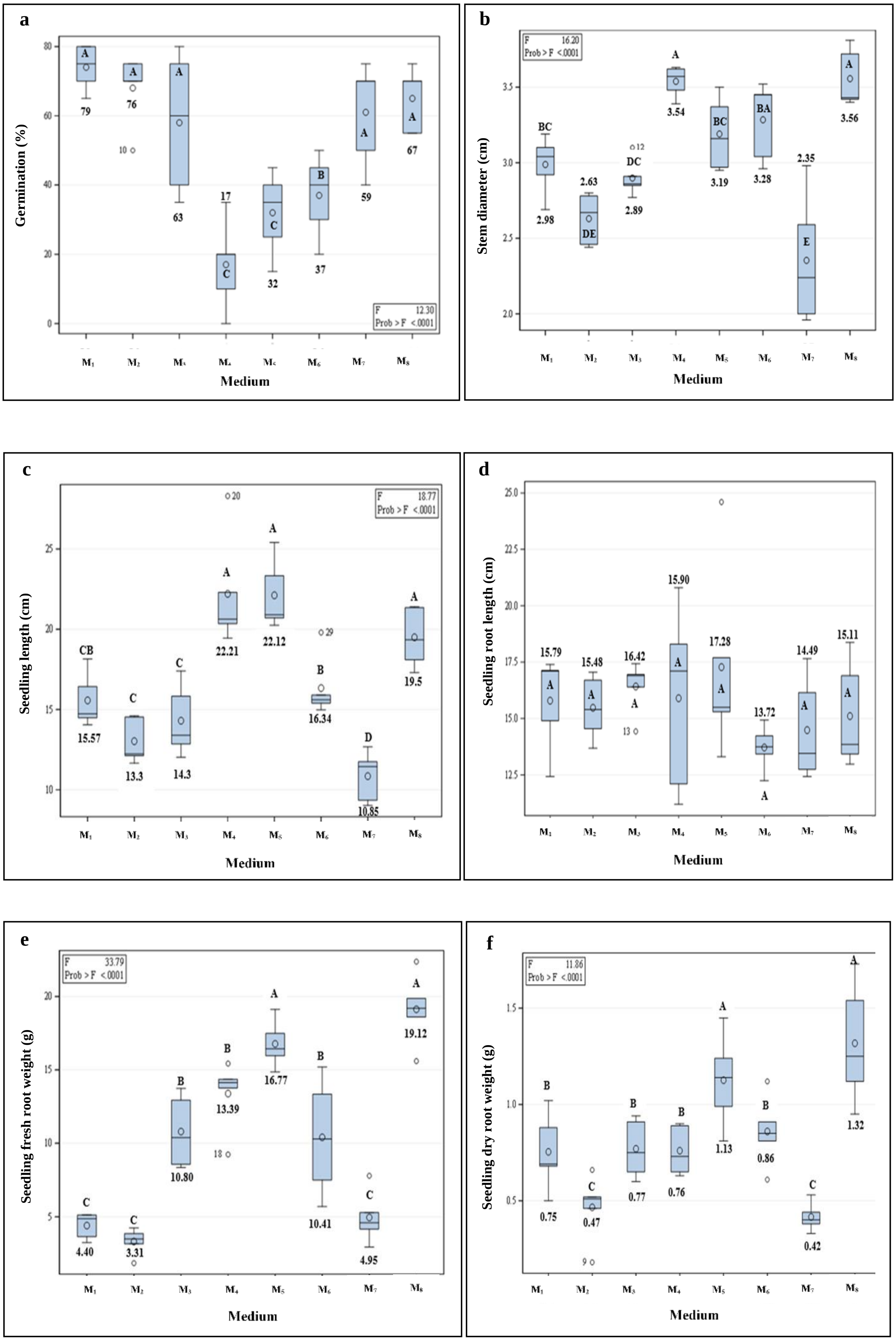


Figure 3. Some measurements of tomato seedlings grown in different growing media a) germination percentage b) stem diameter c) seedling length d) seedling root length e) seedling fresh root weight f) seedling dry root weight g) seedling fresh weight h) seedling dry weight and ı) chlorophyll content.

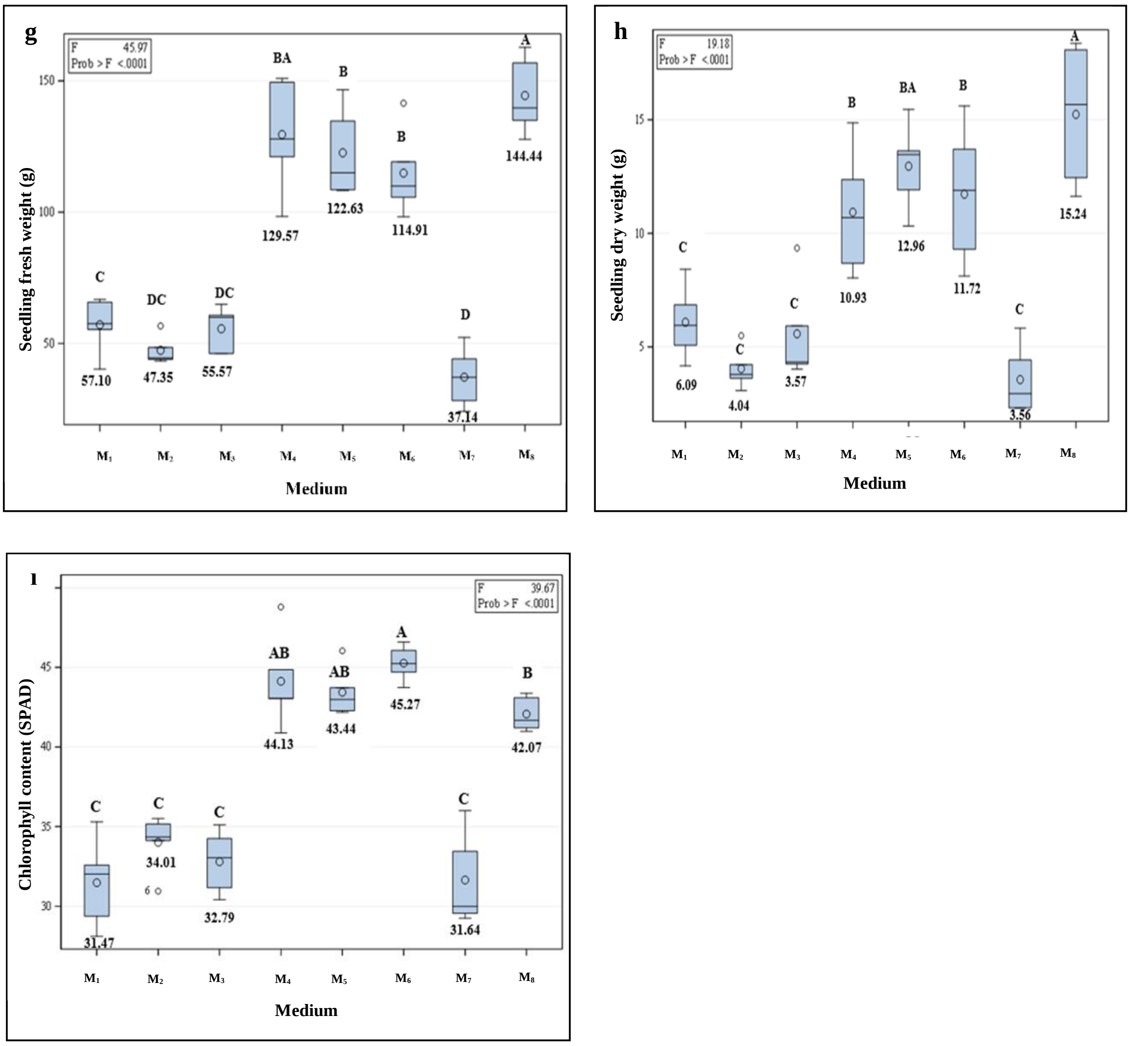


Figure 3. (continued)

may influence the amount of water. M1 and M4 have a more suitable physical structure than the other media due to their richness in fiber content and lowest bulk density values, which may lead to an increase in the amount of water available. Especially M4 has the highest moisture content between 0 kPa and -1500 kPa matric potential values. Therefore, M4 medium can be considered to be the most suitable medium with moisture supply continuity in seedling cultivation.

In almost all applications of soilless substrates, water retention is a decisive factor due to its impact on seed germination and plant growth. Seedling cultivation suffers from high drying rates due to free drainage in the media. The extreme importance of water supply in these situations makes the study of water-holding capacity and the potential increase in substrate formulations important issues. In this sense, the use of alternative substances to increase water retention capacity in soilless substrates is very important. Substances that can increase water-holding capacity have the potential to increase substrate water availability leading to greater plant growth and survival (Farrell et al. 2013). Aeration and water-holding capacity of the growing medium are important for seedling and plant growth. In addition, the water-holding capacity of the growing medium is one of the most effective and important factors in seedling and plant growth (Doneen and MacGillivray 1943; Bradford 1990). Balliu et al. (2017) stated that it is important that the water content of the substrate remains constant until seedling emergence. The physicochemical properties of peat, such as slow decomposition rate, low bulk density, high porosity, high water-holding capacity and high cation exchange capacity, make it suitable as a growing medium for many vegetables and ornamentals (Bohlin and Holmberg 2004).

Soilless growing systems generally use organic or mineral substrates that exhibit limited cation exchange and low buffer capacities, good water permeability, high water storage capacity and adequate aeration. In the absence of chemical and biological interactions, substrate performance depends predominantly on physical properties (Deepagoda et al. 2013). The addition of compounds with chemical activity to the medium may result in some, albeit small, changes in the water retention properties of the medium. This effect can be particularly noticeable in environments with materials that retain water with low strength. In addition to the suitability of the physical properties of the media, especially the high CEC value of M1 media may have had a positive effect on the amount of water retained. Indeed, among the media used in the study, M1 media has the lowest bulk density and the highest CEC value. Organic matter (OM) content and CEC play a vital role in water vapor sorption hysteresis, especially for clay minerals (Arthur et al. 2020). Based on the theory that water molecules form clusters on cations prior to full surface coverage of specific colloidal surfaces (Laird 1999; Prost et al. 1998), it has been confirmed that cation exchange capacity (CEC) and cation type play an important role in water vapor sorption magnitude and hysteresis (Arthur et al. 2019).

The amount of available water and EC level were significant in the germination rate. M4 and M1 medium had higher water retention capacity and water utilization capability than the other media, which led to an increase in the germination percentage in this medium. On the other hand, the lowest germination percentage obtained in M4 medium was attributed to the higher EC value of this medium compared to the other media. As a matter of fact, in some studies, the lowest values in germination percentages were obtained in the environments where vermicompost was used (Atiyeh et al. 2001; Ievinsh 2011; Tan 2014). The highest yield in vegetable cultivation depends on the balance between vegetative growth and generative development (Uzun 2001). Therefore, the relationship between stem diameter and plant height is important in determining the quality of the plant. The short length of the seedlings in the M7 medium is an indication that the seedlings are underdeveloped, and it is thought to be responsible for the thin stem diameters in this medium. The stem's small diameter may lead to variations in nutrient and water transport (Maltaş et al. 2017).

It is not desirable for quality seedlings to be too tall. Abnormalities in height are usually related to the growing medium temperature and the amount of water applied. The temperature regime of the seedling medium is very important for good and uniform germination. For this reason, temperature monitoring during germination is essential. For most crops, the temperature inside the germination room needs to be stable (Kubota et al. 2013). The optimum temperatures for tomato in seedling cultivation are 21-24°C and 18-21°C, respectively. (Balliu et al. 2017). Since the amount of sunlight decreases in winter, the light intensity also decreases. Unless this low light intensity is increased by additional lighting, the optimum temperatures specified for tomatoes should be reduced between 3-5°C according to the light intensity. If the temperature is not lowered, the seedlings will overgrow due to the high temperature (Ekşi 2012). The seedling heights obtained in our study were slightly above the average height (15-18 cm) stated by the seedling companies. This result may be due to the fact that the temperature values indicated in Table 2 in the first two weeks of the study were higher than the desired temperature values. In addition, the fact that no chemicals were used to inhibit the growth of the seedlings may have caused excessive growth of the seedlings. In some studies, on this subject, it was reported that seedling height was higher in environments where compost or vermicompost was used as a mixture (Atmaca 2012; Tan 2014; Sönmez 2017).

In the study, the highest fresh root weight was obtained in M8 medium. This result can be considered as an indication that M8 medium provides better root development. Yılmaz et al. (2017) examined the changes in seedling root weight parameters in different growing media and reported that the best seedling root wet weight results were obtained in the medium with the highest vermicompost ratio. In addition, vermicompost mixture was present in all environments where seedling fresh weight was high (M8, M6, M5 and M4). It was observed that the vegetative part increased in the environments with vermicompost, and it was thought that this effect may be due to the nutrient content of vermicompost and microbial activity in the environment (Atiyeh et al. 2001). On the other hand, Yılmaz et al. (2017) reported that the highest value (110.73 g) obtained in the fresh weight of tomato seedlings grown in different media was in the medium with 80% peat + 20% vermicompost proportional mixture.

High seedling dry weight indicates that the growth rate of the plants is high. In our study, the highest seedling dry weight and seedling height were obtained in M8 medium. This result was parallel with the findings of Uzun et al. (1998). On the other hand, vermicompost mixture was present in all environments (M8, M6, M5, M4) where seedling dry weight was high. Zaller (2007) reported that vermicompost added to the medium significantly affected seedling emergence and biomass distribution (root: shoot ratio) specifically for each tomato variety. The nutrient content and microbial enzyme content of vermicompost (Atiyeh et al. 2001) may be effective in achieving this result. In addition, since seedling fresh weight was low in M7 medium, it was considered to be a normal situation that root dry weight was also low.

Chlorophyll is one of the most important pigments that provide coloration in plants. The amount of chlorophyll in plants varies depending on many factors, such as plant species and growing conditions. It has been reported that it is important to know the average chlorophyll content in plants (Çetin 2017; Zeren et al. 2017), chlorophyll content in leaves affects dry matter production (Taiz and Zeiger 2008), and chlorophyll content is important in terms of quality and yield parameters (Kırbay and Özer 2015). In our study, although the best chlorophyll content was obtained in M6 medium, the chlorophyll content of seedlings in M4, M5 and M8 medium was also high. In conjunctionwith the results obtained in seedling dry weight, the presence of vermicompost in the medium also increased the chlorophyll content of the seedlings.

5. Conclusion

The physical properties of the growth media significantly affected the water content, influencing plant water uptake, yield, and seedling quality. Additionally, the electrical conductivity of the medium's water had a significant negative impact on plant water use. M4 medium retained the most water in its structure. In terms of the amount of available water, M1 and M4 media have approximately 1.5-fold the water content compared to the other media. The fact that both environments have the lowest bulk density played an important role in this effect. While high moisture content was obtained in the media with high organic content, it was determined that the moisture content decreased in the media with high mineral content. Tomato seedling yield and quality parameters (except germination percentage) decreased in the media containing only peat or mixing peat with other materials other than vermicompost. Although vermicompost increased both yield and quality in tomato seedlings, it is amounts greater than 15% in the medium which caused a negative effect on seedling germination. The M8 medium was the most favorable in terms of moisture capacity and other physicochemical properties and was the most suitable medium for tomato seedling growth and quality parameters. In summary, it was determined that the chemical capacities as well as the physical properties of the media to be used in soilless culture are important in terms of tomato seedling yield and quality parameters. For this reason, vermicompost should be included in the mixture in the preparation of growing media, but its proportion in the mixture should not exceed 15%.

Acknowledgement

We thank Akdeniz University Scientific Research Projects Coordination Unit for their support (Project ID: FYL-2018-3114).

References

Abad M, Noguera, P, Bures S (2001) National inventory of organic wastes for use of growing media for ornamental potted plant production: case study in Spain. Bioresource Technology 77(2): 197-200. doi: 10.1016/S0960-8524(00)00152-8.

Arthur E, Tuller M, Norgaard T, Moldrup P, de Jonge LW (2019) Improved estimation of clay content from water content for soils rich in smectite and kaolinite. Geoderma 350: 40-45 doi: 10.1016/j.geoderma.2019.05.018.

Arthur E, Tuller M, Moldrup P, de Jonge LW (2020) Clay content and mineralogy, organic carbon and cation exchange capacity affect water vapour sorption hysteresis of soil. European Journal of Soil Science 71: 204-214. doi: 10.1111/ejss.12853.

Atiyeh RM, Edwards CA, Subler S, Metzger JD (2001) Pig manure vermicompost as a component of a horticultural bedding plant medium: effects on physicochemical properties and plant growth. Bioresource Technology 78: 11-20. doi: 10.1016/S0960-8524(00)00172-3.

Atmaca L (2012) Effects of using vermicompost as seedling growth medium. Ege University Graduate School of Natural and Applied Sciences. Master Thesis, İzmir, Turkey. (In Turkish)

Balliu A, Marsic NK, Gruda N (2017) Seedling production. Good agricultural practices for greenhouse vegetable production in the South East European countries. *Part II. Thematic approach 6. Seedling production.* FAO Plant Production and Protection Peper. ISSN 0259-2517, pp. 189-206.

Barral MT, Moldes AB, Cendon Y, Diaz-Fierros F (2007) Assessment of municipal solid waste compost quality using standardized methods before preparation of plant growth media. Waste Management & Research 25: 99-108. doi: 10.1177/0734242X07075514.

Bohlin C, Holmberg P (2004) Peat dominating growing medium in Swedish horticulture. Acta Horticulture 644: 177-181. doi: 10.17660/ActaHortic.2004.644.22.

Bradford KJ (1990) A water relations analysis of seed germination rates. Plant Physiology 94: 840-849. doi: 10.1104/pp.94.2.840.

Bures S, Landau DP, Ferrenberg AM, Pokorny FA (1993a) Monte Carlo computer simulation in horticulture: A model for container media characterization. Horticultural Science 28: 1074-1078. doi: 10.21273/HORTSCI.28.11.1074.

Bures S, Pokorny FA, Landau DP, Ferrenberg AM (1993b) Computer simulation of volume shrinkage after mixing container media components. Journal of the American Society of Horticultural Science 118: 757-761. doi: 10.21273JASHS.118.6.757.

Çetin M (2017) Change in amount of chlorophyll in some interior ornamental plants. Kastamonu University Journal of Engineering and Science 3(1): 11-19. (In Turkish)

De Boodt M, Verdonck O (1972) The physical properties of the substrates in horticulture. Acta Horticulture 26: 37-44. doi: 10.17660/ActaHortic.1973.26.5.

Deepagoda TKKC, Lopez JCC, Møldrup P, Wollesen de Jonge L, Tuller, M (2013) Integral parameters for characterizing water, energy, and aeration properties of soilless plant growth media. Journal of Hydrology 502: 120-127. doi: 10.1016/j.jhydrol.2013.08.031.

Demiralay İ (1993) Soil Physical Analysis. Atatürk University Faculty of Agriculture Publishing, No: 143, Erzurum, Turkey. (In Turkish)

Doğan D (2003) The effect of chicken manure added growing medium on growth and quality in seedling production of tomato and cucumber. Graduate School of Natural and Applied Sciences Department of Horticulture, Master Thesis, Ankara, Turkey. (In Turkish)

Doneen LD, MacGillivray JM (1943) Germination (emergence) of vegetable seed as affected by different soil moisture conditions. Plant Physiology 18: 524-529. doi: 10.1104/pp.18.3.524.

Ekşi C (2012) Seed Cultivation. General Directorate of Agricultural Research and Policies Alata Horticultural Research Station. Mersin, Turkey. https://www.alata.gov.tr. (In Turkish).

Farrell C, Ang XQ, Rayner JP (2013) Water-retention additives increase plant available water in green roof substrates. Ecological Engineering 52: 112-118. doi: 10.1016/j.ecoleng.2012.12.098.

Fields JS, William C, Fonteno BEJ, Owen JS (2004) Hydro physical properties, moisture retention, and drainage profiles of wood and traditional components for greenhouse substrates. Journal of the American Society of Horticultural Science 49(6): 827-832. doi: 10.21273/HORTSCI.49.6.827.

Gruda N, Qaryouti MM, Leonardi CH (2013) Growing media. In Good agricultural practices for greenhouse vegetable crops. Principles for Mediterranean climate areas. FAO, Plant Production and Protection Paper 217, Rome, pp. 271-302.

Gül A (2012) Soilless Agriculture, ISPN: 978-975-8377-83-1, Hasat Publishing, İzmir. (In Turkish)

Ievinsh G (2011) Vermicompost treatment differentially affects seed germination, seedling growth and physiological status of vegetable crop species. Plant Growth Regulation 65: 169-181. doi: 10.1007/s10725-011-9586-x.

Jackson ML (1967) Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Kacar B (1995) Chemical Analysis of Plant and Soil III. Soil Analysis, Ankara University Faculty of Agriculture Education Research and Development Foundation Publications, No: 3, Ankara, Turkey. (In Turkish)

Kırbay E, Özer H (2015) The Effects of Different Shading Applications on Yield and Quality of Organically Grown Cucumber (*Cucumis sativus* L.) in the Greenhouses. International Journal of Agriculture and Wildlife Science (IJAWS) 1(1): 7-14. (In Turkish)

Kubota CH, Balliu A, Nicola S (2013) Quality of planting material. In Good agricultural practices for greenhouse vegetable crops. Principles for Mediterranean climate areas. FAO Plant Production and Protection Paper Series, Chapter 13, Rome, pp. 355-378. doi: 10.13140/RG.2.1.1934.4808.

Kumar V, Guerreroa FM Tansel B, Savabi MR (2010) Hydro-physical characteristics of selected media used for containerized agriculture systems. Agricultural Water Management 98: 314-320. doi: 10.1016/j.agwat.2010.08.023.

Kutilek M, Novak V (1998) Exchange of water in the soil-plant-atmosphere system. International Agrophysics 12: 28-33.

Laird DA (1999) Layer charge influences on the hydration of expandable 2:1 phyllosilicates. Clays and Clay Minerals 47: 630-636. doi: 10.1346/CCMN.1999.0470509.

Lehman H, Clark EA, Weise SF (1993) Clarifying the definition of sustainable agriculture Journal of Agricultural Environmental Ethics 6: 127-143. doi: 10.1007/BF01965480.

Maltaş AŞ, Hız A, Kaplan M (2017) The Company and Cultivar Effects on Seedling Quality. Academia Journal of Engineering and Applied Sciences 2(3): 48-54. (In Turkish)

Mariyappillai A, Arumugam G (2021) Physico-chemical and hydrological properties of soilless substrates. Journal of Environmental Biology 42: 700-704. doi: 10.22438/jeb/42/3/MRN-1504.

Nelson PV (2012) Root Substrates. In: Greenhouse Operation and Management. 7th Edn., Prentice Hall, Upper Saddle River, NJ., pp. 161-194.

Paradelo R, Moldes AB, González D, Barral MT (2012) Plant tests for determining the suitability of grape marc composts as components of plant growth media. Waste Management & Research 30: 1059-1065. doi: 10.1177/0734242X12451307.

Paradelo R, Vazquez-Nion D, Silva B, González A, Barral MT (2016) Acidification of mixtures of granite powder and compost to prepare nursery potting mixtures. Compost Science & Utilization 24: 1-10. doi: 10.1080/1065657X.2015.1020399.

Pokorny FA, Henny BK (1984) Construction of a milled pine bark and sand potting medium from component particles. I. Bulk density: A tool for predicting component volumes. Journal of the American Society of Horticultural Science 109: 770-773. doi: 10.21273/JASHS.109.6.770.

Pokorny FA, Gibson PG, Dunavent MG (1986) Prediction of bulk density of pine bark and/or sand potting media from laboratory analyses of individual components. Journal of the American Society of Horticultural Science 111: 8-11. doi: 10.21273/JASHS.111.1.8.

Prost R, Koutit T, Benchara A, Huard E (1998) State and location of water adsorbed on clay minerals: Consequences of the hydration and swelling-shrinkage phenomena. Clays and Clay Minerals 46: 117-131. doi: 10.1346/CCMN.1998.0460201.

Raviv M, Chen Y, Inbar Y (1986) Peat and peat substitutes as growth media for container-grown plants. In: Chen, Y., Avnimelech, Y. (Eds.), The Role of Organic Matter in Modern Agriculture. Martinus Nijhoff Publishers, Dordrecht, pp. 257-287.

Raviv M, Lieth JH (2008) Significance of soilless culture in agriculture. Soilless Culture 1-11. doi: 10.1016/B978-0-444-63696-6.00001-3.

Sevgican A (1999) Greenhouse vegetable cultivation (Soilless Agriculture- II) Ege University Publishing. No: 526, İzmir, Turkey. (In Turkish)

Sönmez İ (2017) Determination of the effects on growth and nutrient content of tomato seedlings of spent mushroom compost. Mediterranean Agricultural Sciences 30(1): 59-63.

Sonneveld C (1981) Items for application of macro-elements in soilless culture. Acta Horticulturae (ISHS) 126: 187-195. doi: 10.17660/ActaHortic.1982.126.23.

Taiz L, Zeiger E (2008) Plant Physiology. Sinauer Associates; 3 edition ISBN: 0878938230.

Tan E (2014) Determination of growing environments suitable for organic seedling production. Master Thesis, Ege University, İzmir, Turkey.

TÜİK (Turkey Statistical Institute) (2021) Plant production statistics. https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=1. Accessed 26 December, 2021.

Tüzel Y, Gül A, Daşgan HY, Öztekin GB, Engindemiz S, Boyacı HF (2015) Changes and new searches in greenhouse cultivation. Turkey Agricultural Engineering VIII. Technical Congress, Ankara, Turkey, pp. 658-709. (In Turkish)

United Nations (UN) (2021) UN news: World population. https://www.un.org/en/global-issues/population. Accessed 26 December, 2021.

Uzun S, Demir Y, Özkaraman F (1998) Light interception and plant dry matter accumulation. Journal of Ondokuz Mayıs University Faculty of Agriculture 13(2): 133-154.

Uzun S (2001) Relationships between some growth and yield parameters of tomato and eggplant cultivation in greenhouse and temperature and light. 6. National Greenhouse Symposium. pp. 85-90. (In Turkish)

Wallach R, Da Silva F, Chen Y (1992) Hydraulic characteristics of tuff (scoria) used as a container medium. Journal of the American Society of Horticultural Science 117(3): 415-421. doi: 10.21273/JASHS.117.3.415.

Yelboğa K (2014) Growing power of agriculture: Seedling Industry. Garden News 3(2): 13-16. (In Turkish)

Yılmaz E, Özen N, Özen MÖ (2017) Determination of changes in yield and quality of tomato seedlings (*Solanum lycopersicon* cv. Sedef F1) in different soilless growing media. Mediterranean Agricultural Sciences 30(2): 163-168.

Zaller JG (2007) Vermicompost in seedling potting media can affect germination, biomass allocation, yields and fruit quality of three tomato varieties. European Journal of Soil Biology 43: 332-336. doi: 10.1016/j.ejsobi.2007.08.020.

Zeren İ, Cantürk U, Yaşar MO (2017) Change of chlorophyll quantity in some landscaping plants. Journal of Bartin Faculty of Forestry 19 (2): 174-182. (In Turkish)