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Determination of changes in yield and quality of tomato seedlings (*Solanum lycopersicon* cv. Sedef F1) in different soilless growing media

Farklı topraksız yetiştirme ortamlarında domatesin (*Solanum lycıpersicon* cv. Sedef F1) fide verim ve kalitesindeki değişimin belirlenmesi

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ABSTRACT

In this study, changes in the yield and quality of tomato (*Solanum lycopersicon* cv. Sedef F1) seedlings at different soilless growth media were studied under greenhouse conditions. For this purpose, as a growing medium; peat, zeolite vermicompost and different mixtures of these substrates [Zeolite 100% (M1); Peat 100% (M2); Peat 80% + Vermicompost 20% (M3); Zeolite 80% + Vermicompost 20% (M4); Peat 65% + Zeolite 15% + Vermicompost 20% (M5); Peat 40% + Zeolite 40% + Vermicompost 20% (M6)] were used. At the end of the 45-day trial period, seed germination percentage, seedling height, seedling stem diameter, shoot fresh weight, root length, root weight and plant nutrients content (N, P, K, Ca, Mg, Fe, Zn, Mn and Cu) were determined. In the experiment, media of M5 was found to give the best results for germination percentage, seedling height, root length, seedling fresh weight and root weight parameters of tomato seedling. M1 environment did not make a positive impact on the tomato seedling cultivation. However, the data suggested that it would be useful zeolite in a mixture with other media. Based on the results obtained, the M5 provides more advantageous environment for the development of seedling and it can be readily used in terms of seedlings growing in soilless culture.

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ÖZ

Bu çalışmada, farklı topraksız yetiştirme ortamlarındaki domatesin fide verim ve kalitesindeki değişimler sera koşulları altında araştırılmıştır. Bu amaçla araştırmada yetiştirme ortamı olarak; torf, zeolit ve vermikompost ve bu maddelerin farklı karışımları [Zeolit % 100 (M1); Torf % 100 (M2); Torf % 80 + Vermikompost % 20 (M3); Zeolit % 80 + Vermikompost % 20 (M4); Torf % 65 + Zeolit % 15 + Vermikompost % 20 (M5); Torf % 40 + Zeolit % 40 + Vermikompost % 20 (M6)] kullanılmıştır. 45 günlük deneme periyodu sonunda: tohum çimlenme yüzdesi, fide boyu, fide gövde çapı, fide yaş ağırlığı, kök uzunluğu, kök ağırlığı ve bitki besin element içerikleri (N, P, K, Ca, Mg, Fe, Zn, Mn ve Cu) belirlenmiştir. Araştırmada, çimlenme yüzdesi, fide boyu, kök boyu, fide yaş ağırlığı, kök ağırlık parametrelerinde M5 ortamı en iyi sonuç veren ortam olmuştur. M1 ortamı (% 100 zeolit) domates fide yetiştiriciliğinde olumlu etki meydana getirmemiş ancak diğer ortamlarla karışım halinde kullanılmasının daha uygun olacağı belirlenmiştir. Diğer taraftan, M5 ortamının fide gelişimi bakımından avantajlı olduğu ve topraksız kültürde fide yetiştiriciliğinde rahatlıkla kullanılabileceği belirlenmiştir.

1. Introduction

Greenhouse production area in Turkey is nearly 65 000 ha, and vegetable production is made in about 96% of this area (TUIK 2014). Tomato is located in the first place among the agriculturally important species in terms of production area and greenhouse grown. Vegetable production is conducted intensively in Mediterranean region (especially in Antalya) of Turkey and the production is also possible during winter season. Therefore, Antalya is suitable for growth in any season of the year. Greenhouse cultivation area of Antalya is 26 000 hectares. Tomato is cultivated half of the total area, and produced about 2.5 million tons of tomatoes (Anonymous 2016). In vegetable production, qualified seed and seedling is very important to achieve a good yield. Seedling growth period in plant production is very important stage and has an effect on growing and development of plant, early harvest, total efficiency and fruit number per plant. Seedling productions with traditional methods have caused stress for plants (Marković et al. 1995). The most important factors affecting success in soilless culture include climate, greenhouse construction, seedling and breeding.

Many materials can be used as growing media; they are those which have desirable properties, such as abundant nutrients, high water retention capacity, adequate aeration and easy transportation and availability, to ensure the optimum seedling growth. Among these, perlite, vermiculite, pumice and coco-peat for seedling production are important substrates (Kılıç and Kılıç 2006).

Mainly, there are three types of soilless cultivation based on substrates used: a) with buffering substrates (e.g. peaty substrates) b) with inert substrates (e.g. rock-wool) c) with no substrates (e.g. NFT) (Gül et al. 2005). Substrate culture is gaining importance year-by-year all over the world. The physical and chemical characteristics of substrates used in the production of vegetables are quite diverse, and natural and artificially produced new sources are rearing as a growing media.

Peat, widely used as the growing media and formed by the decomposition of organic materials in soil, is defined as a substance that usually has a colloidal structure and therefore improve the soil structure, water and nutrient holding, and adjusts the soil temperature (Kaşka and Yılmaz 1974). Zeolite is another soilless substrate and a type of inclusion compounds. It is a hydrated aluminosilicate and characterized by three-dimensional networks of SiO_4 and AlO_4 tetrahedral, linked by the sharing of all oxygen atoms (Reháková et al. 2004). Zeolites are characterized to have high ability to lose and gain water and to exchange cations without a major change in its structure (Mumpton 1999; Kithome et al. 1999) and these properties of the zeolites convert the zeolites into a potentially useful substance (Harland et al. 1999).

Vermicompost is defined as the end-product of the breakdown of organic matter by earthworms. The importance of earthworms in the breakdown of organic matter and the release of the nutrients that it contains has been known for a long time. It has been demonstrated clearly that some species of earthworms are specialized to live in decaying organic matter and can degrade it into fine particulate materials, rich in available nutrients, with considerable commercial potential as plant growth media or soil amendments (Edwards and Arancon 2004; Garg et al. 2008). Research into vermicomposting and commercial projects has been developed in many countries (Edwards 2004). In soilless culture, various opinions about substrates used in vegetable production have been reported in many investigations (Demidov et al. 1991; Benitez et al. 1999; Kipp et al. 2000; Butt 2001; Raviv et al. 2002; Chaoui et al. 2003; Nelson 2003; Jones 2005). Organic amendments such as vermicompost also add growth-influencing substances like plant hormones as observed by many researchers (Atiyeh et al. 1999). Thus, the application of vermicompost may affect germination of seed and growth of seedling, and incorporation of vermicompost into growing media has been shown to significantly improve plant growth, since it constitutes a slow-release source of nutrients and also modifies the physical properties of the potting substrates (Chaoui et al. 2003; Hidalgo et al. 2006).

The aim of this work was to evaluate the effects of various growth media mixtures on seedling quality and nutritional contents in tomato (*Solanum lycopersicon cv.* Sedef F1).

2. Materials and Methods

2.1. Materials

This experiment was conducted (November-December 2014) in a greenhouse located at the Seed Research and Development Center of Akdeniz University (36° 54' 0.17" N; 30° 38' 53.30" E) in Antalya, Turkey. The greenhouse is 10 m × 14 m × 6.5 m, and tomato (*Solanum lycopersicon cv.* Sedef F1) was used as the plant material. Temperature of the greenhouse where the experiment was conducted was measured weekly. The lowest temperature during incubation was 26 °C in the 6th week and the highest temperature was 38 °C in the 1th week. Six different growth media used in the experiment (Table 1) and some selected physicochemical properties of these media are given in Table 2.

Research was established according to the randomized complete block design in three replicates. Fourty seeds were sown into each growing medium, totaling 720 seedlings, and the experiment ended after ~45 days. No nutrient or fertilizer was used in this research but seedling trays were regularly irrigated with tap water to maintain humidity suitable for plant growing.

As growing medium, peat (Sılu Kudra), zeolite (Agro Clino), vermicompost (Green-PIK) and mixtures of these media are used in the experiment. These substrates were procured from various commercial vendors. The vermicompost is the end product provided by a "Staratel" earthworm (*Eisenia fetida*) population in the process of treating/enriching especially prepared cattle manure compost. Some specifications of the substrates as provided by their manufacturers are given in Table 3, Table 4 and Table 5. In the study, peat and zeolite individual media used were designated as control treatments.

Table 1. Growing media used in the experiment.

Growing Media (GM)
100% Zeolite (M1)
100% Peat (M2)
80% Peat + 20% Vermicompost (M3)
80% Zeolite + 20% Vermicompost (M4)
65% Peat + 15% Zeolite+ 20% Vermicompost (M5)
40% Peat + 40% Zeolite+ 20% Vermicompost (M6)

Table 2. Some physicochemical properties of the growing media.

GM	Moisture (pF_0) (%)	Moisture ($pF_{1.7}$) (%)	Bulk Density (g cm^{-3})	Porosity (%)	Macro Pore (%)	Micro Pore (%)	pH (1: 5)	EC (µS cm^{-1})
M1	57.61	27.57	0.97	56.12	26.86	29.26	5.9	123.5
M2	157.31	121.64	0.19	31.22	24.13	7.09	5.8	499.7
M3	184.45	146.31	0.19	35.95	28.49	7.46	6.0	709.7
M4	63.21	28.86	0.89	55.99	25.57	30.42	6.0	386.0
M5	116.04	52.93	0.54	62.63	28.57	34.06	6.0	241.0
M6	136.87	103.21	0.38	52.03	39.25	12.78	6.4	670.3

Table 3. Some analytical data of peat stated by the producer company.

Parameters	Values
pH	5.5–6.5
Fulvic Acid (%)	7
Saltiness (g L^{-1})	0.2–1.5
Organic N (%)	0.1
C/N	Max.50
Organic Carbon of Biological Origin (%)	30
Cu (mg kg^{-1})	<150
Zn (mg kg^{-1})	<150

Table 4. Some analytical data of zeolite stated by the producer company.

Parameters	Values
pH	7–8
Porosity (%)	30
Maximum Moisture (%)	20
Total Na (%)	0.5
Total K (%)	1.5
B (mg kg^{-1})	2

Table 5. Some analytical data of vermicompost stated by the producer company.

Parameters	Values
Moisture (%)	40–45
Ash (%)	35–45
Organic Matter (%)	55–65
Humic Substance (%)	25–32
Total N (%)	1.0–2.0
Total P(% P_2O_5)	1.5–3.0
Total K (% K_2O)	1.2–2.0
Ca (%)	4.0–6.0
Mg (%)	0.6–2.5
Fe (%)	0.6–2.5
Mn (mg kg^{-1})	60–80

2.2. Methods

The percentage of moisture at pF_0 and $pF_{1.7}$, macro- and micro- porosity, and total porosity for growing media are determined by using sand-box apparatus according to the principle of the tension methods (Richards 1949). Bulk density was measured using the cylinder method (Black 1965), and pH and EC was measured in a 1:5 (soil:water) aqueous extract (Jackson 1967).

At the end of a trial period of 45 days, germination percentage (%), seedling height (cm), stem diameter (mm), seedling root length (mm), seedling root weight (g), and fresh weight per seedling (g $seedling^{-1}$) were measured in seedlings from the start of seedling until sufficient height for planting. Macronutrient [nitrogen (N), phosphorus (P), potassium (K^+), magnesium (Mg^{2+}), calcium (Ca^{2+})] and micronutrient [iron (Fe^{2+}), zinc (Zn^{2+}), manganese (Mn^{2+}), and copper (Cu^{2+})] contents were also analyzed in order to determine differences observed on yield and quality of tomato seedlings in different growing media.

Plant samples were washed by distilled water and dried in a forced-air oven at 65 ^oC to reach constant weight. After drying, dry weight of seedlings was recorded. The seedlings were ground separately in a stainless mill to pass through a 20-mesh screen and kept in clean polyethylene bags for analysis. Dried seedling samples of 0.5 g each were digested with 10 ml nitric acid (HNO_3) / perchloric acid ($HClO_4$) (4:1) acid mixture on a hot plate. The samples were then heated until a clear solution was obtained. The same procedure was performed several times. The samples were filtered and diluted to 100 ml using distilled water, and the results were obtained using the ICP-OES (Perkin Elmer-Inductively Coupled Plasma). Total N was determined by a modified Kjeldahl method (Bremner 1965); the other elements in wet-digested extracts were determined by spectrophotometer for P (Bray and Kurtz 1945) and atomic absorption spectrophotometer for K^+, Ca^{++}, Mg^{2+}, Fe^{2+}, Cu^{2+}, Zn^{2+}, and Mn^{2+} (Jackson 1962).

All data were analyzed by LSD multiple comparison test ($P \leq 0.05$). All results presented in the text are expressed as mean values (n= 3). Statistical analyses were performed using IBM® SPSS® Statistics 20 software package (IBM Corporation 2016).

3. Results and discussion

Changes in the percentage of germination (%), seedling height (cm), root length (cm), shoot fresh weight (g $seedling^{-1}$), fresh root weight (g $root^{-1}$) and stem diameter (mm) of tomato seedlings in different growing media are given in Table 6.

Considering the percentage of germination, all growing media (GM) had statistically significant effects (P<0.01) and M5 growth media showed the highest increase in germination percentage. The lowest percentage of germination was obtained in M1 and M2 medium (Table 6). Growth media with vermicompost mixtures gave rise to a positive effect on germination. It is thought that hormones and nutrient content in vermicompost can be effective on the germination percentage. In another study, it has been reported that vermicompost led to significant increases in germination rate and plant growth (Edwards and Burrows 1988).

One of the most important factors is the temperature of seed germination. In our study has emerged importance of the mixture level of the growth medium on the environment temperature. Indeed, the highest germination percentage was obtained in the high peat and vermicompost and the lowest zeolite mixture medium. In such growth medium, moisture content and color intensity of the growing medium is considered to be an important factor for heat uptake and distribution by growth media. Carter (2002) stated that temperature control is very important in the seed germination period.

Significant differences (P<0.001) in the other quality parameters of the emerging seedlings at different growth medium (height, root length, fresh weight of seedling and root, and stem diameter) was observed (Table 6). The highest seedling height were obtained in M5 (23.18 cm), M3 (22.01 cm) and M6 (21.74 cm) growth medium. These growth medium have taken place in the same statistical group in terms of their effect on seedling development. The lowest seedling height value (4.88 cm) was obtained in M1 growth medium (Table 6).

Considering the length of seedling roots, significant differences (P<0.001) occurred between the growing media, and seedling root length was obtained at the highest value (14.65 cm) in M2 medium. Meanwhile, the lowest root growth (6.92 cm) was obtained in M1 medium. Seedling root length in other growing medium were realized as M3>M5=M6>M4 (Table 6). Considering the fresh weight per seedling, significant differences (P<0.001) in the fresh weights of the seedlings at different growth media has occurred. The highest fresh weight of seedlings obtained from the four growths medium (M3, M4, M5, and M6), and these environments have taken place in the same group statistically. On the other hand, the lowest fresh weight values of seedling roots (10.84 cm) were obtained in M1 medium. (Table 6).

The effect of growth medium on seedling root fresh weight was significant ($P<0.001$). The highest root fresh weight values in seedlings were obtained in M4, M5 and M6, and these growth mediums have taken place in the same statistical group in terms of their effect. On the other hand, the lowest values of the fresh weight of the root were obtained in M1 (Table 6).

Significant differences ($P<0.001$) were obtained in stem diameter of emerging seedlings at different growth media. The highest values in seedling stem diameter were obtained from the M3, M4, M5 and M6 growth medium, and these growth medium have taken place in the same statistical group in terms of their impact. The lowest value in the seedling stem diameter was obtained in M1 medium (Table 6).

In our study, it was determined that the best growing seedlings were obtained in the environment in which the vermicompost mixture was placed. It is thought that the high biological capacity of vermicompost may be effective in this result. Indeed, when analytical data of vermicompost are analyzed it is understood to include many components which are important for the development of plant growth. Also favorable results are obtained is considered to be also dependent on the physical and physicochemical properties of the prepared mixtures. Considering several physicochemical parameters (moisture retention, temperature, retention of the nutrients and nutrient available etc.) it was concluded that M3, M4, M5 and M6 are the most appropriate growth medium. Arancon et al. (2004) have reported that higher values of germination rate in vermicompost-amended plots may be ascribed to high porosity, aeration, water holding capacity and presence of humic-like materials and other plant growth-influencing substances (such as plant growth hormones) produced by micro-organisms during vermicomposting. In another study, highest homogeneity of seed germination was observed in vermicompost. In addition, plant height, root length and leaf area were higher in vermicompost and biochar than in farmyard manure (Sarma and Gagoi 2015).

Data on the nutrient content of seedlings is presented in table 7. In terms of nutrients content (N, P, K^{+}, Ca^{2+}, Mg^{2+}, Fe^{2+}, Zn^{2+}, Mn^{2+}, and Cu^{2+}) significant variations ($P<0.001$; $P<0.01$) were obtained among growth mediums. Nitrogen (N) content of the seedling was significantly affected ($P<0.001$) by the different growth medium. The highest N value was obtained with M5 medium and the lowest N value with M1 medium (Table 7). The lack of nitrogen content of M1 medium led to the lowest nitrogen concentration in seedlings. Altan et al. (1998) stated that the zeolite does not contain nitrogen. However, it is known that the zeolite has a high ammonia adsorption capacity (Emma et al. 1999). Kurama et al. (1999) stated that due to slow nitrogen release to external ambient by zeolite the effect of zeolite on seed germination, plant growth and development are quite slow.

Phosphorus (P) and potassium (K) content of the seedling was significantly affected ($P<0.001$) by the different growth medium (Table 7). The highest seedling P content was obtained

Table 6. Changes of germination percentage, seedling height, root length, seedling fresh weight, fresh root weight, and stem diameter of tomato (*Solanum lycopersicon* cv. Sedef F1) in different growing media[1].

GM	Germination (%)	Height (seedling) (cm)	Root length (cm)	Fresh weight (seedling) (g)	Fresh weight (root) (g)	Stem diameter (mm)
M1	91c[2]	4.88d	6.92d	10.84c	7.36d	1.51c
M2	92c	11.32c	14.65a	51.36b	15.43c	2.38b
M3	94ab	22.01a	11.99b	110.73a	30.48b	2.93a
M4	93b	18.79b	10.01c	101.07a	47.24a	2.84a
M5	96a	23.18a	11.10bc	110.60a	40.00a	2.93a
M6	93b	21.74a	10.82bc	109.26a	40.64a	2.91a
Mean	93.16	16.99	10.91	82.31	30.19	2.58
LSD (5%)[3]	**	***	***	***	***	***

[1]Values of $n=3$.
[2]The difference between values not shown with the same letter are significant at $P<0.05$ level.
[3]***$P<0.001$, **$P<0.01$

Table 7. Changes of the nutrient contents of the seedling of tomato (*Solanum lycopersicon* cv. Sedef F1) in different growing media[1].

GM	Nutrients (mg kg^{-1})									
	N (%)	P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu
M1	0.050d[2]	385.40e	22093.33c	25090.00	6585.33a	901.23b	237.10a	158.40a	151.30a	9.68a
M2	0.140c	2774.66b	26590.00c	16653.33	1623.00d	916.56b	121.49b	132.46b	46.24b	5.89b
M3	0.260ab	3146.00a	36340.00b	17763.33	2431.00c	1322.00a	103.72b	93.81c	42.87b	4.19c
M4	0.240b	1556.00d	48700.00a	19743.33	3144.66b	976.50b	166.30b	75.98c	41.27b	2.87c
M5	0.310a	3081.00a	41470.00a	16456.66	2316.66c	1016.93b	100.23b	94.82c	37.98b	3.71c
M6	0.260ab	2505.33c	42130.00a	30740.00	2245.33c	949.60b	417.96a	82.37c	47.82b	3.69c
Mean	0.214	2241.00	36220.55	21074.44	3057.66	1013.80	191.13	106.31	61.24	5.00
LSD (5%)[3]	***	***	***	ns	***	***	**	***	***	***

[1]Values of $n=3$.
[2]The difference between values not shown with the same letter are significant at $P<0.05$ level.
[3]***$P<0.001$, **$P<0.01$, ns: not significant.

within M3 and M5 medium, and the lowest seedling P content observed with M1 medium. In addition, purple colorations were seen in seedlings grown in M1 medium, and this purple color formation may be caused by the accumulation of anthocyanins on the leaves of seedlings grown in M1 environment. It is thought that phosphorus availability or phosphorus uptake by the plant may be negatively affect due to the fact that the zeolite media temperature may be lower than that of other environments. The highest seedling K content was obtained in the M4, M5 and M6 growth medium, and K values among these media were found to be similar. The lowest K value was obtained in media M1 and M2.

Changes in the Ca content of the seedlings in all growth media were not statistically significant. On the other hand, differences in the seedlings Mg content at different growth media were significant (P<0.001), and the highest Mg value was obtained in M1 medium (Table 7). Sodium (Na) levels of seedlings in the different growth medium were also significantly (P<0.001) affected. The highest seedling Na content was obtained in M3. Sodium (Na) values of seedlings in other media were found to be similar (Table 7).

Considering the micro- nutrient contents in seedlings, the highest zinc (Zn^{2+}), manganese (Mn^{2+}) and copper (Cu^{2+}) values in tomato seedlings were obtained in M1 medium, and the highest iron (Fe^{2+}) value was obtained in M6 and M1 medium (Table 7).

In our experiment, the scope of nutrient changes of tomato seedling growing in the different growing media it is understood that the media of M3 and M5 is quite appropriate in terms of macro- nutrient contents especially N, P and K. When evaluated in terms of the micro- nutrient contents, it is observed that a lack of micro- nutrient content of seedling (except Fe) in mediums which containing mixtures of peat and vermicompost.

4. Conclusions

According to the data evaluated; the effect of prepared environments on the yield and quality of tomato seedlings is dependent on the physical and chemical differences of the materials used in growth medium. In general, in terms of seedling growth and quality the best results were obtained with mixture of peat and vermicompost growth medium. In practice, peat is generally preferred in seedling production in agricultural sector. However, a mixture of peat + vermicompost might provide better results and can be successfully used in the seedling production. Considering the seedling leaf analysis, the higher N, P and K contents in seedlings were obtained with mixture of peat and vermicompost medium compared with other mediums (especially M1 and M2 medium). Especially M5 growth environment (65% Peat + 15% Zeolite + 20% Vermicompost) provided the best results in the physical seedling quality and efficiency parameters. The fact that the physical, chemical and biological properties (holdings elements, water retention capacity, macro and micro porosity balance, pH, EC, humic and fulvic acid content, and heat retention and heat dissipation capacity etc.) of the M5 environment are at an appropriate level has affected seedling development in the positive direction. The zeolites used in M5 medium can be seen as an important factor for keep the nutrients in environment or provide slow release of nutrient out of the environment. Trinchera et al. (2010) reported that secondary roots and the proliferation of root hairs in maize increase with both micronized and granular clinoptilolite substrates where zeolite particles adhere to the root surface, and this result is related to the enhanced solubilization of organic matter and nutrient availability. In this respect, the M5 growth medium may be seen as an encouraging environment for optimization of root medium and nutrient uptake in soilless culture. Also in this study, it has been understood that need studies to determine the interactions between the vermicompost and other used substrates in soilless culture.

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