Ekoloji 24, 94, 17-24 (2015)
doi: 10.5053/ekoloji.2015.943

Research on the Possibilities of Using Paper Mill Sewage Sludge as an Alternative Seedling Growth Media to Peat

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Abstract

This research was conducted in order for sewage sludge, which complies with the criteria stated in the last 2010 Sludge Regulation on Soil Pollution and its Control, to be used as a seedling growth media. In this research, peat and soil were used as controls, and peat + sewage sludge + perlite and soil + sewage sludge + perlite were mixed at different rates and 8 growing media were prepared for each. Some quality specifications of the tomato seedlings were investigated by determining their nutrient contents in the growth media.

According to the research results, the media mixed with peat was found statistically different at the level of $p<0.05$ in the seedling quality characteristics except for the cotyledon width, and the media mixed with soil was found statistically different at the level of $p<0.05$ in all the determined seedling quality characteristics. The growth media prepared by mixing peat and sewage sludge proportionately had a positive effect on seedling formation. The O5 media, which contained 40% peat + 50% sewage sludge + 10% perlite, had the best values of seedling length, seedling root length, shoot fresh weight, and root fresh weight. In the soil-controlled media, the M5 media, which contained 40% soil + 50% sewage sludge + 10% perlite, had the best values of seedling root length and root fresh weight.

Keywords: Growing media, peat, seedling, sewage sludge.

Kağıt Fabrikası Arıtma Çamurunun Torf'a Alternatif Fide Yetiştirme Ortamı Olarak Kullanılma Olanaklarının Araştırılması

Özet

Bu araştırma; Toprak Kirliliğin Kontrolü ve Noktasal Kaynaklı Kirlenmiş Sahalara dair 2010 yılında Resmi Gazetede yayınlanan yönetmelikte belirtilen kriterlere uygun olan arıtma çamurunun, fide yetiştirme ortamı olarak değerlendirilmesi amacı ile yürütülmüştür. Araştırmada, torf ve toprak kontrol olarak kullanılmış, torf+arıtma çamuru+perlit ve toprak+arıtma çamuru+perlit farklı oranlarda karıştırılarak 8'er yetiştirme ortamı hazırlanmıştır. Yetiştirme ortamlarında bitki besin maddesi içerikleri belirlenerek, domates fidesinin bazı kalite özellikleri incelenmiştir.

Araştırma sonuçlarına göre; torf karışımlı ortamlar, kotiledon genişliği dışında diğer fide kalite özelliklerinde, toprak karışımlı ortamlar ise belirlenen tüm fide kalite özelliklerinde istatistiki olarak $p< 0.05$ seviyesinde farklı bulunmuştur. Torf ve arıtma çamurunun belli oranlarda karışımı ile hazırlanan yetiştirme ortamları fide oluşumuna olumlu etki yapmıştır. %40 torf + %50 arıtma çamuru+ %10 perlit içeren O5 ortamı; fide boyu, fide kök uzunluğu, sürgün yaş ağırlığı ve kök yaş ağırlığı en iyi değerini vermiştir. Toprak kontrollü ortamda ise %40 toprak + %50 arıtma çamuru +%10 perlit içeren M5 ortamı, fide kök uzunluğu ve kök yaş ağırlığı en iyi değerini vermiştir.

Anahtar Kelimeler: Arıtma çamuru, fide, torf, yetiştirme ortamı

Unal M (2015) Research on the Possibilities of Using Paper Mill Sewage Sludge as an Alternative Seedling Growth Media to Peat. Ekoloji 24(94): 17-24.

INTRODUCTION

One of today's most important environmental problems is the disposal of wastes arising from production processes. The lack of enough regular landfill areas and their limited capacity make the problem more complex. The utilization of sewage sludge with a low content of toxic substances and a high content of organic matters and nutrients on agricultural lands is an important solution for the disposal of sewage sludge. The utilization of sewage sludge on agricultural lands is an effective and the cheapest waste disposal method regarding the prevention of environmental pollution and the protection of natural resources (Ayvaz 2000).

When conducting this alternative application, the effects it will create on the soil in terms of salinity should be considered as well as the limit values for heavy metals stated in the regulation on soil pollution and its control (Kocaer and Başkaya 2001). Several studies have been carried out about the

Received: 19.04.2013 / Accepted: 03.09.2014

utilization of sewage sludge on agricultural lands both in Turkey and abroad. In the studies, sewage sludge was applied to soil in increasing amounts and its effect on soil properties and plant development was determined. Hernandez-Apaoloza et al. (2005) stated that the best result was obtained from a 30% sludge application to the soils in increasing amounts.

In the study they conducted, Angin and Yağanoglu (2009) applied sewage sludge to the experimental blocks in increasing amounts and investigated some of the physical and chemical effects it had on soils. As a result of the experiment, they stated that the highest effect on the physical and chemical properties, except for the exchangeable sodium percentage (ESP), occurred during the application of 12 t da^{-1}. Celebi et al. (2011), in the study they conducted in order to utilize sewage sludge as establishment fertilizer in the green area formed with rhizomatous rubra festuca (*Festuca rubra* var. *rubra*), showed that the performance of grass increased with the application of sewage sludge and that the color and grass quality values were high in the dose of 9 and 12 t da^{-1} and recommended it.

The ways of utilization of sewage sludge on agricultural lands were investigated with a different perspective.

In this study, sewage sludge is used as a growth media in seedling production, which is an important input in vegetable growing. Peat is the most commonly used growth media in seedling production and due to the suitability of its physical and chemical properties, it is found alone or as a mixture in the growth media. However, peat, which is intensely used and needed, is a natural and depletable resource. It is stated that peat resources in the world will soon be depleated (Dede et al. 2006, Ostoc et al. 2008, Schmilewski 2008). Therefore, research for an alternative material to peat is gaining momentum in international studies. There are a limited number of studies enabling the utilization of agricultural waste materials on this issue in Turkey. An alternative material to peat should be easily supplied, cheap, and able to provide a contribution to environmental problems.

The purpose of this research is to find solutions for two important environmental problems and try to provide a contribution to plant production.

1. To provide an alternative growth medium material instead of depleted peat resources,

2. To enable the utilization of sewage sludge with a low heavy metal content in agricultural production.

MATERIAL AND METHODS

Materials

The experiment was conducted in the greenhouse of Arslanbey Vocational School of Kocaeli University. Randomized parcels were organized with 3 replications according to the experimental design. The 8 growing media were prepared by mixing sewage sludge with peat and sewage sludge with soil at different rates. In the experiment, the mixture was applied as air-dried on a weight basis. The samples were left for incubation for 10 weeks in room conditions and additional fertilizing was not made in order to see the properties of the media. The composition of the growth media used in the experiment is given in Table 1.

In the experiment, peat was provided from a commercial firm, soil was taken from a depth of 0-30 cm from the Kullar Plantation, the Provincial Directorate of Food Agriculture and Livestock in Kocaeli, and sewage sludge obtained from a paper mill was used. Some chemical properties of the materials used in the experiment are given in Table 2.

The annual production capacity of the paper mill in Kocaeli is 180.000 tons. The amount of annual sewage sludge ranges from 15.000 to 18.000 tons (30% dry matter). A physical dewatering method was applied to the Sludge . The treatment plant consists of physical, chemical, and biological (aerobic) treatment units and has a capacity of 5,000 m^3/day. According to the results of an analysis conducted by Tubitak MAM on behalf of the paper mill, the heavy metal contents in the sewage sludge are lower than the limit values stated in Annex-1-B of the “Regulation on the Use of Domestic and Urban Sewage Sludge in Soil” (Anonymous 2010).

According to the analysis results of the sewage sludge conducted in accordance with the Standard Methods, the heavy metal content of the sludge is as follows: Pb (mg kg^{-1}) < 30, Cd (mg kg^{-1}) < 2, Cr (mg kg^{-1}) < 30, Cu (mg kg^{-1}) 91, Ni (mg kg^{-1}) 12, Zn (mg kg^{-1}) 56, and Hg (mg kg^{-1}) < 0.5. The sludge sample taken for the experiment was added to the mixture after it was air-dried. The media was irrigated in field capacity throughout the experiment. At the end of the incubation period, 3 tomato seeds were planted in each pot. The certified tomato seeds were bought from a private company and type H-2274 was used. In the first weeks of the experiment, the hypocotyl length, cotyledon length, and width were measured and recorded. At the end of the experiment, the seedling length, seedling root length, shoot fresh weight, and root fresh weight were determined.

Methods

Analyses of pH, EC, organic matter %, total N, available P, exchangeable Ca, Mg, K, and extractable Fe, Cu, Zn, and Mn micro nutrients and heavy metals such as Pb, Cd, Cr, Ni, and Hg were conducted on the sewage sludge, before the peat and soil were added to the mixture prior to the incubation. In the growth media available in each pot after the harvest of the plants, the following were analyzed: the pH and EC were measured with a pH meter and EC meter (Richard 1954) in 1:2.5 media: the distilled water suspension, the organic matter by the Walkle-Black wet combustion method (Jackson 1962), the total N by the Kjeldahl method (Bremner 1965), the available P by $NaHCO_3$ extraction (Olsen et al. 1954), the exchangeable K by the ammonium acetate method in an atomic absorption spectrophotometer (Knudsen et al. 1982), and the exchangeable Ca and Mg by the ammonium acetate method in an atomic absorption spectrophotometer (Thomas 1982). Fe, Cu, Zn, and Mn that could be extracted by DTPA were determined in an atomic absorption spectrophotometer (Lindsay and Norvell 1978). The heavy metals that could be extracted by DTPA (Dietilen Triamin Penta Asetik Asit) were extracted according to Lindsay and Norvell (1978), and the analyses were performed with an Inductively Coupled Plasma Spectrophotometer (ICP).

Statistical evaluations were made according to the One Way-Anova program. As a result of the variance analysis, different groups were determined by using the Duncan test.

RESULTS

Some chemical properties of the growth media mixtures are given in Table 3 and Table 4. In Table 3, when some of the chemical properties of the growth media mixtures formed with the peat, sewage sludge and perlite they were considered, the pH was found to be 7.10-7.22 and the EC value was found to be 1100-1850 μS/cm. The content of organic matter in the media ranges from 15.59% to 29.53% and the content of N ranges from 0.87% to 1.58%. The content of available P_2O_5 in the media varies between 13.70 and 32.14 mg kg^{-1}. The exchangeable K_2O content of the media was found to be between 135.52 and 378.16 mg kg^{-1}, exchangeable Ca content between 1750 and 3147.25 mg kg^{-1}, and exchangeable Mg content between 465 and 680.75 mg kg^{-1}.

In Table 4, when some of the chemical properties of the growth medium mixtures formed with the peat, sewage sludge, and perlite they were considered, the pH is between 7.28 and 7.20 and the EC value varies from 1268.00 and 732.00 (μS/cm). The organic matter content in the media ranges from 18.95% to 2.35%, and the nitrogen content varies between 0.94% and 0.20%. The available content ranges from 13.73 to 32.14 mg kg^{-1}. The exchangeable K_2O content of the media is between 118.24 and 378.16 mg kg^{-1} , exchangeable Ca content between 1650.00 and 3147.25 mg kg^{-1}, and the exchangeable Mg content between 250.15 and 471.25 mg kg^{-1}. The microelement contents of the

Table 1. Growing media and mixing ratios

Media	Mixing ratios	%		%	%
O1	Peat	100			
M1	Soil	100			
O2	Peat	90	Perlite	10	
M2	Soil	90	Perlite	10	
O3	Peat	80	Sewage sludge	20	
M3	Soil	80	Sewage sludge	20	
O4	Peat	60	Sewage sludge	30	Perlite 10
M4	Soil	60	Sewage sludge	30	Perlite 10
O5	Peat	40	Sewage sludge	50	Perlite 10
M5	Soil	40	Sewage sludge	50	Perlite 10
O6	Peat	20	Sewage sludge	80	
M6	Soil	20	Sewage sludge	80	
O7-M7	Sewage sludge	90	Perlite	10	
O8-M8	Sewage sludge	100			

Table 2. Some chemical properties of the materials used in the research.

Property	Peat	Soil	Sewage sludge
EC(μS/cm)	1980	860	1485
pH	7,05	7,25	7,20
N(%)	1,50	0,24	0,98
Available P (mg kg-1)	13,79	14,30	32,28
Exchangeable cations (mg kg-1)			
K	143,35	121,95	379,62
Ca	1605,00	1730,12	3147,25
Mg	680,75	271,06	471,25
Organic matter (%)	33,25	2,94	19,80
Available heavy metals (mg kg-1)			
Fe	93,28	23,40	56,68
Cu	1.42	1,25	10,14
Zn	1,26	1,28	18,83
Mn	11,71	14,91	23,56
Pb	0,374	0,329	1,003
Cd	0,095	0,032	0,082
Ni	4,472	0,161	0,655
Cr	0,001	-	0,058
Hg	0,005	0,011	0,021

Table 3. Some chemical properties of the growing media mixtures.

Growing media	pH	EC (µS/cm)	OM (%)	N (%)	P_2O_5 (mg kg^{-1})	K_2O (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
O1	7,10	1850,00	29,53	1,47	13,79	143,12	1605,00	680,75
O2	7,12	1806,00	28,30	1,46	13,70	135,52	1550,00	600,20
O3	7,15	1680,00	29,43	1,37	18,19	158,00	1980,00	560,25
O4	7,16	1501,00	28,64	1,58	20,40	190,85	2170,00	510,00
O5	7,18	1430,00	27,10	1,35	22,20	218,60	2430,00	500,25
O6	7,21	1229,00	26,03	1,29	25,21	260,10	2750,00	490,75
O7	7,20	1100,00	15,59	0,87	28,34	320,28	2860,00	465,00
O8	7,22	1268,00	18,95	0,94	32,14	378,16	3147,25	471,25

Table 4. Some chemical properties of the growing media mixtures.

Growing media	pH	EC (µS/cm)	OM (%)	N (%)	P_2O_5 (mg kg-1)	K_2O (mg kg-1)	Ca (mg kg-1)	Mg (mg kg-1)
M1	7,28	736,00	2,41	0,21	14,27	121,63	1730,12	271,06
M2	7,27	732,00	2,35	0,20	13,76	118,24	1650,00	250,15
M3	7,26	745,00	4,76	0,26	13,73	134,60	1860,00	290,45
M4	7,24	757,00	4,96	0,24	14,23	168,35	1930,00	320,45
M5	7,23	764,00	5,69	0,28	21,20	237,50	2120,00	370,20
M6	7,22	1073,00	9,10	0,45	30,01	300,62	2470,00	430,50
M7	7,20	1100,00	15,59	0,57	28,35	320,28	2860,00	465,00
M8	7,22	1268,00	18,95	0,94	32,14	378,16	3147,25	471,25

Table 5. Micro elements of the growing media mixtures.

Growing media	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})
O1	92,85	1,09	1,26	11,51
O2	92,20	1,08	1,24	10,46
O3	91,83	1,66	2,62	10,33
O4	90,91	1,81	2,87	10,65
O5	86,78	3,55	5,18	12,40
O6	84,83	5,41	7,69	12,20
O7	29,41	5,57	11,61	14,68
O8	56,66	10,02	16,71	22,64

Table 6. Micro elements of the growing media mixtures.

Growing media	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})
M1	23,37	1,25	1,21	14,25
M2	21,40	1,20	1,11	12,85
M3	23,56	1,29	1,80	13,66
M4	23,34	1,30	1,44	13,02
M5	22,72	1,68	1,77	10,69
M6	34,16	4,28	4,52	12,77
M7	29,41	5,57	11,61	14,68
M8	56,66	10,02	16,71	22,64

growth media mixtures are given in Table 5 and Table 6. In Table 5, when the microelement contents of the growing media mixtures are considered, the available Fe content of the media ranges from 29.41 to 92.85 mg kg^{-1}. The available Cu content was found to be between 1.08 and 10.02 mg kg^{-1} , the available Zn content between 1.24 and 16.71 mg kg^{-1}, and the available Mn content between 10.33 and 22.64 mg kg^{-1}. In Table 6, when the microelement contents are considered, the available Fe content of the media ranges from 21.40 to 56.66 mg kg^{-1}. The available Cu content was found to be between 1.20 and 10.02 mg kg^{-1}, available Zn content between 1.11 and 16.71 mg kg^{-1}, and the available Mn content between 10.69 and 16.71 mg kg^{-1}.

The effects of the applications of the growth media mixtures on some quality specifications of the tomato seedlings are given in Tables 7 and 8. When we consider the value of the hypocotyl length of the tomato seedlings used for the applications of the growth media mixtures, the highest value obtained was from O3 at a rate of 47.70 mm and the lowest value obtained was from O4 at a rate of 34.05 mm, the highest value of cotyledon length obtained was from O1 at a rate of 21.33 mm and the lowest value obtained was from O4 at a rate of 16.35 mm, and the highest value of cotyledon width obtained was from O2 at a rate of 7.16 mm and the lowest value obtained was from O4 at a rate of 6.00 mm. A statistically significant relationship was found between the applications of different growth media mixtures with the hypocotyl and cotyledon lengths at a level of 5%. Statistically, there is no difference between the applications of growth media mixtures and cotyledon width. Of the seedling quality characteristics in Table 7, the highest values of seedling length, seedling root length, shoot fresh weight, and root fresh weight were obtained from the O5 media and the lowest values were obtained from the O7 media. A statistically significant relationship was found between the growth media mixtures and seedling length, seedling root length, shoot fresh weight, and root fresh weight at a level of 5%. The O5 media contains 40% peat, 50% sewage sludge, and 10% perlite. The O7 medium contains 90% sewage sludge and 10% perlite.

As for the tomato seedlings used for the applications related to the growth media mixtures in Table 8, the highest value of hypocotyl length obtained was from the M3 media at a rate of 46.83 mm and its lowest value obtained was from the M1 medium at a rate of 33.00 mm. The following, M3, M6, M7, and M8 are statistically in the same letter group. The highest value of the cotyledon length obtained was from the M2 media at a rate of 22.00 mm and its lowest value obtained was from M2 at a rate of 15.66 mm. The M2 and M3 media are statistically in the same letter group. The highest value of cotyledon width obtained was from the M3 media at a rate of 7.76 mm and its lowest value obtained was from M5 at a rate of 5.66 mm.

In Table 8, the lowest values in the measurement of seedling length, seedling root length, shoot fresh weight, and root fresh weight obtained were from the M1 media. The highest value of seedling length obtained was from the M6 media at a rate 17.60 cm, the highest value of seedling root length obtained was from M8 and M5, from the same letter group, at a rate of 16.65 cm, the highest values of shoot

Table 7. Some quality values tomato seedlings affected by the growing media used.

Growing media	Hypocotyl lenght (mm)	Cotyledon length (mm)	Cotyledon width (mm)	Seedling lenght (cm)	Seedling root length (cm)	Fresh shoot weight (g)	Fresh root weight (g)
O1	47,00 d	21,33 b	6,83	19,80 c	17,42 b	8,55 a	0,38 cd
O2	39,53 b	20,13 ab	7,16	15,52 ab	16,35 ab	8,29 a	0,30 ab
O3	47,70 d	19,00 ab	7,00	23,50 d	18,20 b	11,33 b	0,40 d
O4	34,05 a	16,35 a	6,00	18,95 bc	17,90 b	8,97 a	0,38 cd
O5	35,83 a	16,81 a	6,33	24,80 d	18,60 b	12,52 b	0,42 d
O6	43,13 c	17,50 ab	6,80	18,30 abc	16,45 ab	7,85 a	0,37 bcd
O7	43,36 c	18,00 ab	6,16	15,25 a	14,50 a	7,25 a	0,28 a
O8	46,45 cd	17,25 ab	6,35	16,80 abc	16,65 ab	7,44 a	0,32 abc

* Means with different letters in the same row, $p < 0.05$ level, there is a difference.

Table 8. Some quality values of the tomato seedlings affected by the growing media used.

Growing media	Hypocotyl lenght (mm)	Cotyledon length (mm)	Cotyledon width (mm)	Seedling lenght (cm)	Seedling root length (cm)	Fresh shoot weight (g)	Fresh root weight (g)
M1	33,00 a	21,00 cd	6,50 abc	8,76 a	7,55 a	3,10 a	0,03 a
M2	40,50 bc	22,00 d	7,50 bc	11,35 b	12,60 b	4,25 b	0,09 a
M3	46,83 c	20,60 d	7,76 c	13,73 c	12,90 b	6,32 c	0,09 a
M4	40,50 bc	16,60 ab	7,50 bc	15,25 cd	14,16 bc	7,43 d	0,27 b
M5	34,20 ab	15,66 a	5,66 a	15,10 cd	16,60 e	7,20 cd	0,35 c
M6	42,00 c	20,50 bcd	6,66 abc	17,60 e	15,92 de	7,49 d	0,30 bc
M7	43,36 c	18,00 abcd	6,16 ab	15,25 cd	14,50 cd	7,25 cd	0,28 bc
M8	46,45 c	17,25 abc	6,35 abc	16,80 de	16,65 e	7,44 d	0,32 bc

* Means with different letters in the same row, $p < 0.05$ level, there is a difference.

fresh weight obtained were from the M4, M6, and M8 media, and the highest value of root fresh weight obtained was from the M5 media at a rate of 0.35 g.

DISCUSSION

In this research, the chemical properties of the growth media mixtures shown in Table 3 were compared with other studies. Sağlam et al. (2009) found the pH range of the peat samples ranging from 4.25 to 7.36. In the studies carried out, it was stated that as the amount of sewage sludge increased, the pH value also increased (Krogstad et al. 2005, Jamali et al. 2008). Kirven (1986) states that the EC (electrical conductivity) values must be between 2-4 dS/m in the growth media. According to this result, the growth media does not have any problems associated with salinity. Tolay et al. (2000) found the amount of organic matter to be between 15.28% and 37.34% and the amount of nitrogen to be between 0.81% and 1.30% in the growth media that they prepared by mixing organic wastes with sewage sludge and stated that the media showed an enrichment in organic matter and nitrogen. Sağlam et al. (2009) stated that the P_2O_5 content of the peat samples were between 0.17 and 13.90 mg kg^{-1}.In our research, as the amount of sewage sludge in the growing media increased, the P_2O_5 content of the media also increased. Ünal and Katkat (2003) also stated that as the amount of sewage sludge increased, the P_2O_5 content of the soils also increased.

When we compare the values in Table 4 with the other studies, the pH range is in a neutral level according to Richards (1954). A high pH decreases the microelement and Fe intake in the plants (Kacar and Katkat 1998). According to Richards (1954), the media is a salt-free category. As the sewage sludge increases, the organic matter content of the media also increases. According to Anonymous (1990) the limit values used for the evaluation of soil productivity analysis results, the N% content of the media is between high and very high. It may result from the high level of nitrogen content in the sewage sludge. According to the data of the Anonymous (1990), the phosphorus content of the media is between sufficient and high. Lundin et al. (2004) stated that the main advantage of using sewage sludge in agriculture was its contribution to the recovery of phosphorous and the other nutrients. In Table 3 and 4 the Ca and Mg values of the media are at a sufficient level according to the data of the Anonymous (1990) and that the Ca element encouraged root development. It was stated that particularly the elements including P, Ca, and Mg had to be found in the seedling growth media as the main elements (Perez-Murcia 2006).

When the micro element contents of the growth media mixtures were compared in Table 5, the available Fe content of the media is at a sufficient level (Korkmaz and Şendemirci 2008). Cu is more than 0.2 mg kg^{-1}, which is a sufficient limit value (Follet 1969). The Zn value is between sufficient and high. The excess may result from the high zinc content of the sewage sludge. However, the Zn content of the media was found to be lower than the limit value of 300 mg kg^{-1} allowed for the soils whose pH values are more than 6 (given by the Regulation on the Control of Soil Pollution). The Mn content of the media is at a sufficient level in the O7 and O8 growth media and at a low level in the others (Anonymous 1990).

When the micro element contents of the growing media mixtures were compared in Table 6, Turan et al. (2010) determined the available Fe content of the soils as ranging from 2.86 to 26.40 mg kg-1 in the study they conducted and stated that there was no iron deficiency in the alluvial agricultural soils of Bursa province. According to Follet (1969), the Cu content of the medium was at a sufficient level. According to Anonymous (1990), the amount of Zn was very high in M7 and M8, high in M6 and sufficient in M1, M2, M3, M4, and

M5. As the amount of the sludge increased in the media, the amount of zinc increased as well. According to the limit values used in the evaluation of a nutrient determined in the soil, Mn was at a “sufficient” level in media M8, where sewage sludge was used, and at a “low” level in the others (Anonymous 1990).

According to these results, it can be said that the (O) media, which were formed by the mixture having peat, sewage sludge, and perlite, and (M) media, which were formed by the mixture having soil, sewage sludge, and perlite, are at a “sufficient” level in terms of macro and micro nutrient contents.

When the effects of some of the quality characteristics of the tomato seedlings on the growth media were compared, O1, which was comprised of 100% peat, O2, with 90% peat +10% perlite, and O3, with 80% peat + 20% sewage sludge, gave the best values, while the O4 media, with 60% peat + 30% sewage sludge + 10% perlite, gave the lowest values during the first weeks of the seedling growing period. The reason for this can be that the seedlings require suitable ventilation, humidity, and temperature conditions from the nutrient during the stages of seed germination and seedling formation. The best values were obtained from the M3 medium, which contained 80% soil + 20% sewage sludge, and the M2 media, which contained 90% soil + 10% perlite, during the first weeks of seedling formation in the media with the soil mixture.

When the seedling formation was completed, the O5 media, with 40% peat, 50% sewage sludge, and 10% perlite gave the highest value and the O7 media, with 90% sewage sludge and 10% perlite, gave the lowest value. The reason for this may be that the need of the plant for nutrients increases during the stage of seedling development and that the addition of sewage sludge makes the growth media enrichment only in some macro and micro elements. When the seedling formation was completed, the lowest values in the media mixed with soil were obtained from the M1 growth media, with 100% soil, and the M5 media, with 40% soil + 50% sewage sludge + 10% perlite, on the seedling root length and root fresh weight. In their study, Tolay et al. (2000) prepared a different growth media mixture to use for the production of ornamental plants and obtained the best result from the mixture with two parts of composted corn stalk with sludge + 1 part of sandy loam soil + 20% agricultural perlite. The growth media mixed with peat provided better values on some quality properties of the tomato seedlings when compared to the growing media mixed with soil.

In the studies they carried out, Şahin et al.(1998), Baran et al. (2001), and Çinkılıç et al. (2008) suggest the mixtures containing 100% peat and those mixed with peat as a growth media.

In this research, the O3 media (80% peat + 20% sewage sludge), which is statistically in the same letter group with the O5 medium (40% peat + 50% sewage sludge + 10% perlite), can be suggested as appropriate mixtures for seedling growing. Ostoc et al. (2008) stated in their research that the applications of municipal solid waste and sewage sludge compost could be used as an alternative growth media to peat in seedling growing. Türkmen et al. (2001), stated that municipal-based sewage sludge had a positive effect on the emergence and seedling quality of cucumber. Hernandez-Apaolaza (2005) recommended a mixture with 30% of sewage sludge compost in the use of growth media for ornamental plant production and emphasized its economical and environmental importance. In their studies, Dede et al. (2006), Akyüz and Kırbağ (2009), and Guerin et al.(2001) determined that organic materials mixed with peat instead of peat and some agricultural and industrial wastes could be used in the growth media in plant production. Jayasinghe et al. (2010) used peat as a control and prepared media containing varying amounts of peat with sugarcane-based sewage sludge and synthetic aggregates in their study. At the end of the experiment, they determined that the growth media having the mixture of sewage sludge, synthetic aggregates and peat improved better than the controlled peat according to the growth and nutrition of the plant.

In conclusion, the use of sewage sludge taken from the treatment plants of the paper mills will provide an important contribution to the solution related to the disposal of sewage sludge and it will also be an alternative material to the endangered peat resources. However, the salinity value, heavy metal, and toxic substance contents of the sludge should be taken into consideration regarding the use of sewage sludge.

ACKNOWLEDGEMENT

This work and for the laboratory support we wish to thank The Republic of Turkey Ministry of Food, Agriculture and Livestock, Kocaeli Provincial Directorate and Food Control Laboratory Kocaeli Provincial Directorate.

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