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Araştırma Makalesi/Research Article

Effects of Different Soil Conditioners on Water Use Efficiency and Tomato Plant Growth in Loam and Clay Loam Soils

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Abstract

Experiment was consisted of two different soil textures (clay loam and loam), four treatments (8% olive pomace compost, 4% perlite, 0.12% hydrophilic polymers and control) with three replications. Tomato (*Lycopersicon lycopersicum* L.) seedlings were transferred to each pot and plants were grown under controlled atmosphere conditions. Effects of different soil conditioners on plant water use efficiency and tomato plant growth were determined. As a result, olive pomace compost applications to loam soil saved irrigation water 45.12%, 42.99% and 38.88% compared to control, perlite and hydrophilic polymers treatments respectively. On the other hand, hydrophilic polymers treatments saved irrigation water 17.82%, 46.76% and 27.29% compared to control, perlite and olive pomace compost treatments respectively for clay loam soil. Soil pH decreased and electrical conductivity (EC) increased for both soils after the experiment. The highest soil EC value was detected with the application of olive pomace compost. Perlite application increased plant fresh weight and length while olive pomace compost increased branch numbers of tomato for clay loam soil. Root length and surface areas were maximum under olive pomace compost applications for both soils.
Keywords: Soil conditioner, water use efficiency, tomato, olive pomace compost, hydrophilic polymers

Farklı Toprak Düzenleyicilerin Tın ve Killi Tın Topraklarda Su Kullanım Randımanına ve Domates Bitkisinin Büyümesine Etkileri

Öz

Bu çalışma iki farklı tekstür (tın ve killi tın), dört farklı uygulama (kontrol, % 8 pirina kompostu, % 4 perlit ve % 0.12 su tutucu polimer) ve üç tekerrürden oluşmaktadır. Bitki büyüme odasında yürütülen bu çalışmada, toprak düzenleyicilerin toprak nemine, bazı toprak özelliklerine ve domates bitkisinin (*Lycopersicon lycopersicum L.*) bazı bitkisel özelliklerine etkileri belirlenmiştir. Çalışma sonucunda, tınlı toprakta pirina kompostu uygulamasına kontrol, perlit ve su tutucu polimer uygulamalarına göre sırasıyla % 45.12, % 42.94 ve % 38.88 oranında daha az sulama suyu verilmiştir. Killi tın toprakta ise su tutucu polimer uygulaması ile kontrol, perlit ve pirina kompostu uygulamalarına göre sırasıyla % 17.82, % 46.76 ve pirina % 27.29 oranında daha az sulama suyu verilmiştir. Deneme sonunda her iki toprakta da pH düşmüş ve elektriksel iletkenlik (EC) artmıştır. En yüksek EC pirina kompostu uygulamasında bulunmuştur. Killi tın toprakta en fazla bitki yaş ağırlığı ve bitki boyu perlit uygulamasında, en fazla bitki dal sayısı pirina kompostu uygulamasında bulunmuştur. Her iki toprakta da en fazla kök uzunluğu ve kök alanı pirina kompostu uygulamasında olmuştur.
Anahtar kelimeler: Toprak düzenleyici, su kullanım randımanı, domates, pirina kompostu, su tutucu polimerler

Introduction

Drought has been dramatically increasing across the worldwide and therefore water must be used more efficiently. Adding certain organic substances and soil conditioners particularly into sandy soils with low aggregate stability and water holding capacity improves the water retention capacity of such soils (Brady and Weil, 2008). There are many types of organic or inorganic substances available that may be used to regulate soil water properties. However; these substances should not be harmful to environment and plant development. Perlite and hydrophilic polymers are inorganic soil conditioners and they are widely available in markets. Perlite is a volcanic glass containing more than 1% water. and it softens when it reaches temperatures of 800-900 °C. Perlit's volume increases about 20 times of its original volume to create an expanded and porous material when it is heated rapidly (Yurkov and

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Aksel'rod, 2005) Initial research on synthetic polymers showed great promise in improving soil aggregation, soil water holding capacity and prevent erosion (Wallace and Wallace, 1986). Gel-forming, cross-linked polyacrylamides can be used to overcome short term or persistent drought which inhibits plant growth (Johnson, 1984). Hydrogels absorb and store water hundreds of times their own weight (Bowman and Evans, 1991). The uses of alternative water holding amendments and irrigation methods will become more important, especially in regions have water scarcity on the other hand they are too expensive for widespread use (Wallace and Wallace, 1986). The correct use of hydrophilic polymers has great importance for agricultural production especially under drought and semi-drought climates because it diminishes the negative effects of water-scarcity (Han et al., 2010). Direct use of olive pomace restricts the plant's development that is because phenol substances and organic fatty acids contained in the plant cannot transform into humic substances (Ilay et al., 2013). Therefore, olive pomace should be used in agriculture after making compost (Gonzalez et al., 1990; Kavdır and Killi, 2008) which is ecologically friendly soil conditioner and it can be used as a considerable source for increasing the carbon content in soil and improving soil aggregate stability (Kavdır and Killi, 2008). Addition of olive pomace compost (OPC) to sandy clay loam soil increased available water for plant growth and improved hydraulic characteristics of soils. Results suggest that OPC may also serve as effective organic conditioner to improve soil hydraulic properties (Killi et al., 2014).

The fact that the ratio of water and air in the soil is within certain limits is very important in terms of normal development of the plants. For this reason, it is necessary to control the amount of water in the root zone and to determine irrigation amount accurately. Direct and indirect methods can be used to determine soil water contents. Using FDR sensor (Leib et al., 2003) does not require much labor, save time and can be placed at desired soil depth.

The aim of this research was to determine effects of different soil conditioners on soil properties (water contents, pH and electrical conductivity), tomato plant growth (the number of branches, plant height and fresh weights, plant water use efficiency, root parameters) and total irrigation water amount.

Materials and Methods

Properties of soils used in the study

Loam and clay loam soil samples were taken from 0-20 cm soil depths from Çanakkale Onsekiz Mart University-Dardanos Campus and Lapseki province in Çanakkale. Texture, pH, electrical conductivity (EC), field capacity, bulk density and wilting point of these soil samples are presented in Table 1**.**

Table 1. Some physical and chemical properties of soils

Soil	Sand (%)	Silt (%)	Clay (%)	Texture	pH (1:2.5)	EC (µS cm^{-1})	Bulk density (g cm^{-3})	Field Capacity PV (%)	Wilting Point PV (%)
Lapseki	49.95	28.51	21.54	L	8.05	115.80	1.42	33.74	15.08
Dardanos	35.82	24.91	39.27	CL	7.77	201.90	1.30	47.74	18.53

Properties of olive pomace compost

The olive pomace compost (OPC) was prepared by using olive pomace (50%), 30% poultry manure, 10% alfalfa, 5% olive leaves, 5% soil and approximately 5 L of water was added in the composting bins. Some chemical parameters of the olive pomace compost areas follow; pH :8.83, EC: 2830µS cm^{-1}, C: 27.10%, N: 1.74%, C: N ratio: 15.57.

Experimental design and planting

Lycopersicon esculentum Mill. cv. H-2274 was selected as the tomato varieties. Peat was selected as the germination media. Three seeds were planted in each seedling pots and they were placed to incubator at 22°C for germination experiment. The seeds started to germinate eight days

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after sowing. Soils were sieved through a 6mm-sieve and olive pomace compost (8% w/w), perlite (4%), and hydrophilic polymer (0.12%) were mixed with soils and placed in pots (3-L volume). Average size of OPC and perlites were 2 mm and between 2-4 mm respectively. Soil without any amendment was used as a control treatment and all treatments were replicated three times. Tomato seedlings were transplanted in the pots and then they were placed to growth chamber as a randomized block design. Plant growth chamber's temperatures were set between 24-27 °C and humidity's were between 70-75% during the experiment. Plants were grown for 27 days and then above ground parts of tomato plants were cut from soil surface and fresh weights were determined.

Fertilization

Mono ammonium phosphate (MAP) and potassium sulphate (PS) fertilizer solutions were prepared in accordance with the ratios of 300 kg ha^{-1} N, 150 kg ha^{-1} P and 600 kg ha^{-1} K. Fertilizer solutions were applied at planting and it was applied several times with the irrigation water during the experiment.

Soil moisture data recording

Loam and clay loam soils were sieved through a 6 mm sieve and filled into 3000 cm^3-pots. Previously their water content at saturated conditions and at field capacity were determined in order to calculate the quantity of the irrigation water (Table 2). The moisture change was measured with the help of FDR sensors. Moisture sensors were calibrated by adapting the technique recommended by Starr and Paltineanu (2002). Weight of pots including soil and water was recorded. FDR sensors were placed in soil vertically and calibrated for each soil texture and soil plus conditioners mixtures The coefficient of determination (R^2) was found to be over 0.90 for all treatments. The data measured by the sensors were stored by data recorders with hourly intervals. The stored data were transferred from the data recorders to the computer through USB connection (Demirel and Kavdır, 2013). Irrigation water quantity was determined by using the calibration data in accordance with the Equation (1). Inadequate amount was calculated by subtracting current moisture from field capacity (Table 2) value. Unit was converted from percentage to ml by using soil weights in the pots. The quantity of decreased water is determined with 5-day intervals in ml.

$$dn = FC - CM \quad (1)$$

In the equation; dn: net quantity of irrigation water (ml), FC: field capacity (%) CM: current moisture (%)

Table 2. Field capacity, wilting point and available water contents for loam and clay loam soil

Treatments	Field Capacity PV (%)		Wilting Point PV (%)		Available Water Content PV (%)	
	Loam	Clay loam	Loam	Clay loam	Loam	Clay loam
Control	20.79	31.46	10.72	18.58	10.07	12.88
Perlite	23.93	30.26	13.70	19.47	10.23	10.79
Olive pomace compost	29.07	35.52	17.86	22.66	11.21	12.87
Hydrophilic polymer	22.99	34.16	12.17	19.49	10.82	14.67

PV: percent by volume

Determination of evaporation

In order to determine evaporation, a certain amount of water was filled into an approximately 3000 cm^3 vessel and water height was measured every single day during the testing period; and the evaporation was determined according to the amount of water decreased.

Soil analytical methods

Gravimetric water content was determined by the difference between moist weight and oven-dried (at 105 °C for 24 h) weights of soil samples. Soil pH was determined through the potentiometric measurement of the hydrogen ion concentration in 1:2.5 soil-water mixture with a pH meter (İnoLab, WTW); and the electrical conductivity through the electrical conductivity method with an EC meter (Crison CM-35) (Black, 1965). Compost pH and EC were measured in 1:10 compost-water mixture. Soil texture was determined using the hydrometer method (Gee and Bauder, 1986). Field capacity and wilting point determined with the help of pressure chambers (Soil Moisture Equipment Corp, USA). Field capacity value ranges between 10 kPa (Romano and Santini, 2002) and 33 kPa (Orfánus and Eitzinger, 2010) depending on soil texture.

Plant measurements and analysis

The number of branches of tomato plants was determined by counting, Tomato plants were cut from the soil surface and the height was determined by measuring with a ruler.

Root analytical methods

The roots were pulled and removed from soils. Roots were placed in a container filled with water and they were filtered through 0.163 mm sieve. This process has continued several times. Root parameters such as root length (cm) and root surface area (cm^2) were determined in digitized root images using WinRhizo Basic 2007 (Regent Inst) program.

Water use efficiency

Water use efficiency was calculated with the help of the equation 2.

$$WUE = PFW/QIWP \quad (2)$$

In the equation: WUE: Water Use Efficiency, PFW: Plant's Fresh Weight (g), QIWP: Quantity of Irrigation Water Provided (ml).

Statistical analysis

Duncan test was conducted to provide significant differences ($P<0.05$) between pH, EC, quantity of irrigation water applied, tomato plant's fresh weight. Analysis was conducted by using SAS programme (SAS, 1999).

Results and Discussion

Effects of different soil conditioners on soil water

In this study, the coefficient of determination (R^2) was found to be over 0.90 for all treatments. Cardenas-Lailhacar and Dukes (2010) reported the positive relation between the volumetric water content obtained from FDR sensors and the water content determined through the gravimetric method in their study. They found the average R^2 value was 0.934 that was close to our data. Starr and Paltineanu (1998) reported that the correlation coefficient was 0.992 in their study. Fazackerley and Lawrence (2010), compared the amount of controlled irrigation water used under normal conditions and controlled irrigation water with the help of FDR sensors. They reported that they saved 47% of water as a result of the study.

Control soils received the highest amount of dn and followed by P, HP and OPC respectively (Table 3). The difference among treatments were found to be statistically significant in terms of dn for loam soil ($P<0.05$). Total quantity of irrigation water applied to the OPC treatment was significantly lower than other treatments. OPC treatment received 45.12%, 42.94% and 38.88% less irrigation water compared to control, P and HP treatments respectively. Conservation of soil moisture by application of OPC has also been reported by other researchers. Bouranis et al. (1995) reported that the water retention capacity of the soil mixed with the compost composed of olive oil waste water and olive oil solid waste would be two times more in comparison with pure soil. El-Asswad et al. (1993) mentioned that addition of oil cake significantly increased ($p\leq0.05$) the water retention of two sandy soils studied under all applied tensions. P treatment saved 3.83%, HP treatments saved 10.22% water compared to control treatment for loam soil. Effects of treatments for clay loam soil was found to be significant in terms of total dn applied ($P<0.05$) (Table 3). Total dn of P treatment was greater than dn of other treatments for clay loam soils. P treatment received 46.76%, 35.22% and 26.78% more water than HP, control and OPC treatments respectively (Table 3). Amendments of oversize fragments such as large granules of perlite will increase the air-filled porosity (Caron et al., 2005) and drainage. Evans and Gachukia (2007) mixed different ratios of perlite to rice hulls and when perlite ratio increased from 20% to 60% and water holding capacity reduced from 67.9% to 59.0%. HP treatment received the lowest quantity of irrigation water for clay loam soil. It saved 17.82%, 46.76% and 27.29% irrigation water compared to control, OPC and P respectively. The variations in hydrophilic polymers effects on soil water characteristics and plant growth changes according to type of hydrophilic polymers, plant types and soils (Akhter et al, 2004). Several studies (Abedi-Koupai and Asadkazemi, 2006; López-Elías et al., 2013; Yang et al., 2014; Mazen et al., 2013). have reported that applications of hydrophilic polymers increased soil water holding capacities.

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Table 3. Quantity of irrigation water applied to loam and clay loam soil.

Treatments	Total irrigation water applied (ml)	
	Loam	Clay loam
Control	1374.80±113.85**A**	597.52±78.37**B**
Perlite	1322.23±78.50**A**	922.31±59.02**A**
Olive pomace compost	754.50±29.33**B**	675.37±24.17**B**
Hydrophilic polymer	1234.34±97.31**A**	491.08±117.36**B**

Differences between the averages specified with different capital letters in the same column are significant and they indicate the difference between treatments (n=3, P < 0.05).

Effects of different soil conditioners on pH and EC of soils

Average pH and EC values were reported at Table 4. The differences among treatments for loam soil and clay loam soil were statistically significant (p<0.05). An initial pH value was 8.05 in loam soil (Table 1) and it ranged between 7.48-7.83 at the end of the experiment. In clay loam soil; the pH value was initially 7.77 (Table 1) and ranged between 7.52-7.69 at the end of the study. The reason of reduced pH could be the application of the acid-based MAP and PS fertilizers during the experiment. HP treatment had the lowest pH value among all treatments for loam soil while both HP treatment and OPC had the lowest pH value for clay loam soil (Table 4). The pH value of HP was neutral. Research on four different super-absorbent polymers (SAP) showed that the effects of SAPs on soil pH and EC were contrary (Bai et al. 2010). pH values of the P and OPC applied soils were similar to that of the control soil. Hachicha et al. (2006) reported that compost made of olive oil wastes and poultry manure did not have any adverse effects on soil pH value. The lowest pH value was obtained from the OPC treatment for clay loam soil (Table 4). Nektarios et al. (2011) reported decrease in pH value as the compost was mixed into the soil. An initial EC value of loam soil was 115.80 µS cm^{-1} (Table 1) and it ranged between 437.50-878.33 µS cm^{-1} and the initial EC value was 201.90 µS cm^{-1} for clay loam soil (Table 1) and it ranged between 763.67-1475.33 µS cm^{-1} at the end of the experiment. Application of soil conditioners increased EC values in both soil types (Table 4). On the other hand, EC values of both soil types classified as non-saline soil according to Richards' (1954). The highest EC value was observed in the OPC treatment (1475.33 µS cm^{-1}) and the lowest EC was in the P treatment (779.00 µS cm^{-1}) for loam soil. The results show that OPC decreased soil pH and increased EC at the end of the study. EC value of OPC was 2830 µS cm^{-1}, it is possible to conclude that EC value increased in either loam soil or clay loam soil subsequent to the treatment. Increase of soil EC after the addition of olive pomace and OPC were also reported by Kavdır and Killi (2008) and Ntoulas et al. (2011).

Table 4. Effects of different soil conditioners on soil pH and EC

Treatments	**pH (1:2.5)**		**EC (µS cm^{-1})**	
	Loam	Clay loam	Loam	Clay loam
Control	7.80±0.06**A**	7.67±0.05**A**	437.50±46.51**B**	763.67±30.33**B**
Perlite	7.83±0.07**A**	7.69±0.05**A**	476.33±94.66**B**	779.00±59.27**B**
Olive pomace compost	7.78±0.07**A**	7.52±0.09**B**	878.33±60.07**A**	1475.33±45.90**A**
Hydrophilic polymer	7.48±0.03**B**	7.56±0.07**B**	438.00±50.72 **B**	897.67±93.39**B**

Differences between the averages specified with different capital letters in the same column are significant and they indicate the difference between treatments (n=3, P < 0.05).

Effects of different soil conditioners on plant growth and water use efficiency

Treatments did not have significant effect on brunch numbers, height (Table 5) and weight (Table 6) of tomato plants in loam soil on the other hand their effects were found significant in clay loam soil (P<0.05). Plant fresh weight and height were the greatest in P treatment (60.16 cm and 33.83 g respectively), the highest number of plant branches was found in the OPC (10.30) application in clay loam soil. However, the number of plant branches in P treatment is close to that of OPC treatment. Control soils had the lowest tomato fresh weight for both soil types. The highest tomato fresh weight was obtained from OPC treatment (23.16 g) while it was the lowest in control (10.14 g) treatment for

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loam soil, but this values were not statistically significant (P<0.05) (Table 6). It is well known that additions of organic material to soils enhance plant growth. Cucci et al. (2008) applied 210 t ha^{-1} olive pomace to soil and soil organic matter increased 84%. Montemurro et al. (2004) reported that applications of olive oil waste water and olive compost as an organic fertilizer increased rye-grass growth compared to unfertilized treatment. Co-composting products of olive oil processing wastewater and solid residue applied to soil 25% w w^{-1} and plants grown in these mixtures were 1.52-8.5% times larger than those grown on a sandy loam soil (Bouranis et al., 1995). Evans and Gachukia (2004) reported that tomato plants grown in perlite and sphagnum peat mixture containing 20% to 40% perlite had significantly higher dry shoot weights than those grown in same amount of fresh rice hulls-sphagnum peat mixture. Papafotiou et al. (2005) were placed OPC, peat and perlite in pots by mixing in different ratios. They reported that OPC is effective in increasing the height of the *Ficus benjamina* L. plant. Ozenc and Ozkan (2003) investigated the effects of peat and perlite addition to soil on the development of the pepper plant under water stress. Peat and perlite increased pepper development compared to soil alone.

Water use efficiency (WUE) as affected by different soil amendments are presented in Table 6. There was a decrease in tomato fresh weight and WUE in the control treatment compared to other treatments. WUE was the highest in OPC (0.030 and 0.040 g ml^{-1}) and the least in control (0.007 and 0.010 g ml^{-1}) treatments for loam and clay loam soils (Table 6). P treatment has low water holding capacity therefore increasing the irrigation water can also improve plant growth under P treatment. Plant growth was enhanced by applications of OPC (Montemurro et al., 2004; Killi et al., 2014). Hydrophilic polymers did not effect on WUE thus López-Elías et al. (2013) observed no positive effects of polyacrylamide-based hydrophilic polymer (PAM) on WUE of plant.

Table 5. Plant branch number and plant height in different treatments

Treatments	**Number of plant branches**		**Plant height** (cm)	
	Loam	Clay loam	Loam	Clay loam
Control	8.00±0.00 **A**	8.0±0.00 **B**	42.50±8.50 **A**	36.83±5.73 **B**
Perlite	8.00±0.87 **A**	10.00±0.57 **A**	47.66±5.13 **A**	60.16±0.44 **A**
Olive pomace compost	8.60±0.33 **A**	10.30±0.66 **A**	50.83±3.09 **A**	47.66±5.13 **B**
Hydrophilic polymer	9.60±0.66 **A**	7.00±0.57 **B**	48.66±3.38 **A**	39.00±2.65 **B**

Differences between the averages specified with different capital letters in the same column are important and they indicate the difference between treatments (n=3, P < 0.05).

Table 6. Fresh weight and water use efficiency of tomatoe plants in different treatments

Treatments	**Plants fresh weight** (g)		**Water use efficiency** (g ml^{-1})	
	Loam	Clay loam	Loam	Clay loam
Control	10.14±1.99 **A**	6.25±1.06 **B**	0.007	0.010
Perlite	20.84±1.16 **A**	33.83±4.00 **A**	0.015	0.036
Olive pomace compost	23.16±5.97 **A**	26.64±5.45 **A**	0.030	0.040
Hydrophilic polymer	15.98±2.57 **A**	6.78±0.87 **B**	0.012	0.013

Differences between the averages specified with different capital letters in the same column are important and they indicate the difference between treatments (n=3, P < 0.05).

Effects of different soil conditioners on plant root parameters

Effect of soil conditioners on tomato root length and root surface area was statistically significant for both soil types. The highest root length was recorded in OPC applied soils. OPC significantly increased root length in a loam (186%), and a clay loam (486%) soils. Similarly, OPC also significantly increased root surface area by 212% and 392% in a loam and clay loam soil

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respectively (Table 7). Roots grown in HP treated soils showed the weakest development in a loam soil. Some researchers reported that hydrogel application reduced root and shoot growth of plants (Keever et al., 1989) and negatively affected plant growth (İşlek and Öztokat Kuzucu, 2018). In this research amended clay loam soil by OPC, P and HP enhanced plant root growth. OPC application increased root length by 5.9, 1.3, and 3.7 fold compared to control, P and HP treatments respectively, in a clay loam soil (Table 7). Killi et al (2014) also reported that root length and surface area increased with 8% OSWC application. OPC increased root surface area 3.1, 3.6, and 4.0-fold compared to control, P and HP treatments respectively in a loam soil.

Table 7. Plant root length and root area in different treatments

Treatments	**Root length** (cm)		**Root surface area** (cm^2)	
	Loam	Clay loam	Loam	Clay loam
Control	469.80±87.26**B**	155.30±60.02**B**	41.07±3.50**B**	13.07±2.33**C**
P	469.30±105.42**B**	704.80±214.36**BA**	36.14 ±1.86**B**	38.30±4.39**B**
OPC	1345.40±404.53**A**	910.60±165.52**A**	128.28±0.92**A**	64.38±1.78**A**
HP	247.70±22.56**B**	247.70±22.56**B**	31.72±2.57**B**	23.53±2.89**CB**

Differences between the averages specified with different capital letters in the same column are important and they indicate the difference between treatments (n=3, P < 0.05).

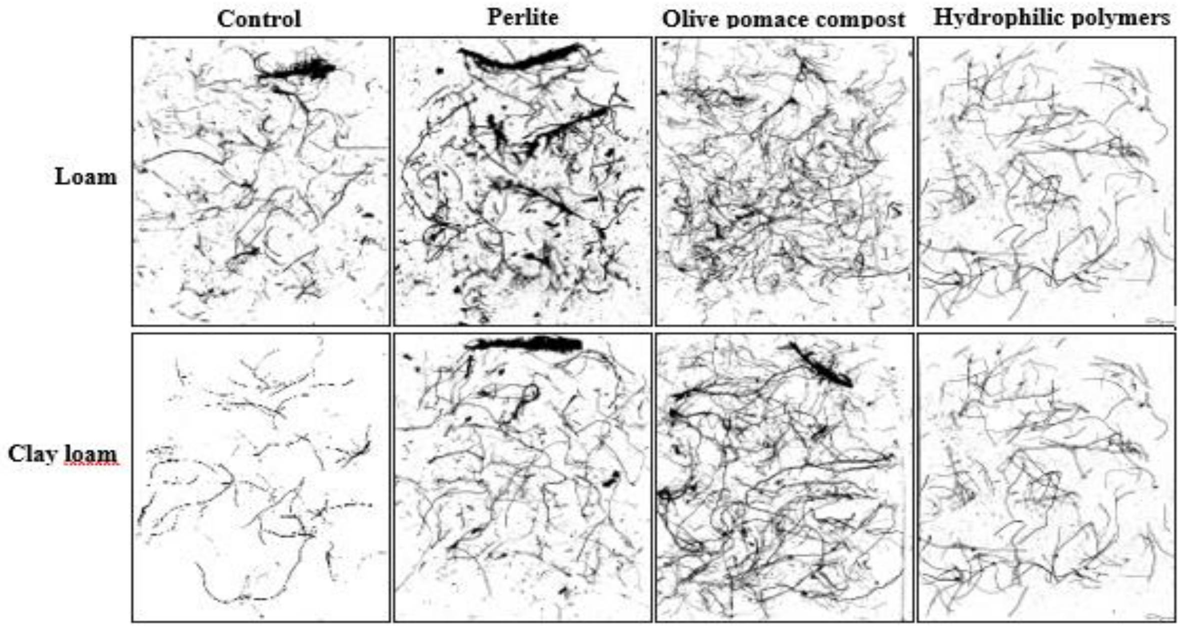

Figure 1. Plant root images of different applications in loam and clay loam soil

Conclusion

In this study, four different treatments including soil alone, 8% OPC, 4% P and 0.12% HP were used and replicated three times in loam and clay loam soils. Study was conducted under controlled atmosphere conditions and effect of soil water contents, pH and electrical conductivity, tomato plant growth (the number of branches and leaves, plant height, fresh and dry weights, plant water use efficiency, root parameters) and total irrigation water amount have been determined. Consequently; it is possible to conclude that P, HP and OPC which were mixed with soils conserved much more soil water compared to control soils. However; especially OPC preserved more water, increased tomato growth compared to other treatments in loam soils. Both tomato plants shoot and the root growth of OPC applied loam soil was significantly higher than those in the control treatment. Application of P increased tomato plant growth in clay loam soils but this material does not conserve water in the soil compared to other treatments. HP saved water in clay loam soil, but it had contributed the least to the development of tomatoes among other treatments. P, OPC and HP applications

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increased WUE by 114.29, 328.57, 71.43% respectively in loam soil and by 260.00, 300.00, 30.00, respectively in clay loam soil compared to control treatment. In this research HP was applied at the rates of 1.7 and 1.6 t ha^{-1} while application rates of OPC were 114 and 104 t ha^{-1} for loam and clay loam soils, respectively. Cost of both amendments (HP and OPC) per year is nearly equal. Therefore, it can be suggested to apply OPC to the soil every year, since it increases plant water use efficiency and plant growth especially in loam soils compared to HP.

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