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Study of Changes in Soil Moisture and Salinity Under PlasticMulch and Drip Irrigation in Pistachio Trees

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Abstract

In this study, changes in soil moisture and salinity contents in drip irrigation combined with white and black plastic mulches compared to no mulch (control) was evaluated. The experiment was carried out in two commercial pistachio orchards (Ohadi cultivar) with irrigation frequencies of 8 to 12 days with a total water consumption 4100 and 6170 m^3ha^{-1}. The study was conducted in a complete randomized block design with three replicates from 2014-2015. Results showed that plastic mulches significantly affected the studied parameters, such as dry yield and water use productivity (WUP). The WUP in plastic mulch treatments increased from 36% to 100% compared to the control. On the other hand, soil moisture content in plastic mulches were up to 12% higher than control in irrigation intervals in both orchards. Moisture content equations between two consecutive irrigations obtained in depth of the maximum root development (25 to 75cm). Proper irrigation frequency in pistachio trees with sandy loam to loamy sand soil was determined based on the derived equations and PWP and RAW in soil experimental plots. The frequency was six to eight days in the case of no mulch, and in the use of plastic mulch, it was 11 to 15 days. The results showed that the use of plastic mulch decreased the soil surface salinity from 30.8% to 51.8% compared to the control. The amount of water consumption, irrigation frequency, soil texture and sampling points affected the soil surface salinity. The average salinity of 0-120cm soil depth was reduced from 20.4% to 27.7% compared to the no mulch treatment. The mulch color did not have a significant effect on any of the parameters.

Keywords: Irrigation frequency, Pistachio, Polyethylene mulch, PWP, RAW, WUP.

Introduction

Irrigation plays an important role in crop production and agricultural development in arid and semi-arid regions. In arid and semi-arid, 40% to 70% of water loss is from soil surface evaporation, which can be prevented by soil covering materials (Jalota, 1993). In addition to facilitating adequate leaching of the salts added through saline water irrigation, soil and water management approaches should attempt to reduce unproductive water losses associated with evaporation from soil surfaces, increase soil moisture storage, maintain soil physical properties in root zone, enhance soil organic matter inputs and nutrient availability status and maintain soil salinity and sodicity levels within acceptable crop production limits. Mulching, out of all the above mentioned, has potential to enhance soil quality over the long-term, as

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well as increase production (Brainard and Bellinder, 2004; Kasirajan and Ngouajio, 2012; Taparauskiene and Miseckaite, 2014).

Burt *et al*. (2002) showed that applying straw mulch on bare soil reduced water evaporation from 11% to 84% in a short period of time and one-half these rates in the long term. In addition, Research Results of Barajas–Guzman *et al.* (2006) and Mahadeen (2014) indicated that the soil moisture content was higher in plots mulched with polyethylene than in bare soil plots. The use of plastic mulch in tomato plants reduced water consumption up to 20% as well as increasing water use productivity (WUP) by 30% (Jolaini, 2011).

Seifi and Rashid (2007) compared surface irrigation systems and drip irrigation with and without plastic mulch on melon crop. The results showed that the drip irrigation system with plastic mulch had the greatest effect on yield (27.7 tons per hectare) and WUP (0.91 tons per hectare in cm of consumed water). In this study, the yield of surface and drip irrigation systems without mulch was 22.47 and 24.54 tons per hectare, respectively, and WUP was 0.57 and 0.72ton per hectare in cm of consumed water in these two systems, respectively. Moniruzzaman *et al.* (2007) reported that plastic mulch, pruning levels and their interaction had a significant effect on yield and some yield components of pear. Mulching in combination with 50% pruning gave the highest number of fruits (151 per plant) and the highest fruit yield (20.87 t/ha).

Transparent and black plastic mulches had significant effects on the survival rate of cuttings of berry (increase to 34.5%), good seedling production (increase to 30%) and the level of weed control (reducing weed dry weight to 775 grams during the three years) compared to other treatments (Ghadiri *et al*. 2008). Moreover, transparent plastic mulch showed increased survival rates of cuttings and seedling production compared to the black plastic mulch.

It has been shown that different types of mulches could significantly increase soil moisture storage in flood irrigation in pistachio orchards. The effect of plastic mulch was more pronounced compared to the other mulches such as straw, sand and plow to retaine the soil moisture in longer period of time (Eslami and Farzamnia, 2009).

Research has shown that plastic mulch had a significant role in preventing the movement of salt to the soil surface (Young, 1984). In China, the use of plastic mulch in corn field significantly decreased salinity in the soil surface compared to no mulch (Hezhong *et al*. 2009. and Danierhan *et al*. 2013). Reducing salts rise to the soil surface and reducing leaching requirement by use of mulch have been reported by Patil-shirish *et al*. (2013).

Studies on the effect of mulch color on squash plant showed that the red mulch had higher beneficial effects on quality and quantity of yield in squash (Fatemi *et al.*, 2013). Afshar *et al.* (2013) also showed that the plastic mulch reduced weed growth, increased plant height as well as yield and WUP in respect to no mulch. In addition, the black plastic mulch was more effective than white plastic mulch and the control.

Although microirrigation methods reduce water consumption due to a reduction in the wetted surface of the soil and improves irrigation efficiency, there are still significant amounts of wasted irrigation water through soil surface evaporation and transpiration by weeds.

There is minimal information on the beneficial effects of plastic mulches in pistachio orchards of Iran. Therefore, the aim of this study was to evaluate the effects of covering lateral tubes with plastic mulches with respect to total yield, WUP and changing of soil moisture and salinity in pistachio orchards.

Materials and Methods

The field experiments were carried out in two commerical pistachio orchards (Ohadi cultivar), which were 35 years old, in the western suburb of Rafsanjan. The chemical analysis of water and soil in the experimental orchards are given in Tables 1 to 3.

The experiment was carried out in two commercial pistachio orchards (Ohadi cultivar) with irrigation frequencies of eight to twelve days with a total water consumption 4100 and 6170m^3ha^{-1}. The study was conducted for eight months during growing season from March until the end of November.We used a completely randomized block design with three replicates during 2014-2015. In both orchards, the irrigation system were two-rows surface drip irrigation with emitters 4 liters per hour. Trees in orchard 1 did not grow well. However, trees in orchard 2 showed good growth and yield, despite that the water consumption was less than in orchard 1.

The used plastic mulch were resistant to UV (UV= 1.5) with thickness of 45 microns, width of 110cm and black and white (light gray) colors. Treatments included drip irrigation without mulching as a control (C), with white (M_W) and black (M_B) mulch. To compare treatments, the quantity of yield and WUP were determined. Mean comparisons were made using Duncan's new multiple range test at 5% probability. The plastic cover eliminates the surface evaporation and as a consequence, affects capillary rise of water to the soil surface.Moisture and soil salinity changes in soil moisture between two consecutive irrigation were determined by sampling in the center of wetting pattern from emitters in a depth of 0-80cm during July and August (the most evaporation time). To measure soil salinity, samples were collected at a depth of 0-40, 40-80 and 80-120cm at the end of the growing season.

Table 1. Some chemical characters for studied water

Experimental orchards	EC_w (dS/m)	pH	The concentration of anions and cations (meq/liter)						SAR $(meq/lit)^{1/2}$
			Co_3^{-2}	Co_3H^-	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	
Orchard1	5.4	8.2	-	0.4	41.5	15.5	13.0	25.8	6.8
Orchard2	5.2	7.5	-	0.6	38.0	16.0	11.0	24.1	6.6

Table 2. Some physical characters for studied soil- orchard 1

Soil depth (cm)	Percentage of soil particles			Soil texture	Bulk density (gr/cm^3)	Volumetric soil water content (%)			TAW[1] (%)
	Sand	Silt	Clay			FC[2]	PWP[3]	RAW*[4]	
0-40	75.0	11.4	13.6	Sandy Loam	1.56	18.8	7.6	10.4	11.2
40-80	83.1	8.7	8.2	Loamy Sand	1.55	16.1	6.7	9.0	9.4
80-120	81.8	10.8	7.4	Loamy Sand	1.55	16.3	7.1	9.4	9.2

*This column by taking 75% of the maximum allowable deficit (MAD[5]) of the total available water is obtained (Alizadeh, 2003).
1- Total Available Water, 2 - Field Capacity, 3 - Permanent Wilting Point, 4 - Redily Available Water, 5 - Maximum Allowable Deficit

Table 3. Some physical characters for studied soil- orchard 2

Soil depth (cm)	Thesoilparticles (%)			Soil texture	Bulk density (gr/cm^3)	Volumetric soil water content (%)			TAW (%)
	Sand	Silt	Clay			FC	PWP	RAW*	
0-40	77.7	10.0	12.3	Sandy Loam	1.53	19.4	8.3	11.1	11.1
40-80	76.7	12.0	11.3	Sandy Loam	1.50	19.8	8.5	11.3	11.3
80-120	81.0	9.4	9.6	Loamy Sand	1.55	17.5	8.1	10.4	9.4

*This column by taking 75% of the maximum allowable deficit (MAD) of the total available water is obtained (Alizadeh, 2003).

Results

The effect of different treatmentson dry yield and-WUP

***Orchard1*:** The results showed that the plastic mulches significantly affected the yield and WUP compare to no mulch ($p \leq 0.05$). In total, the use of plastic mulch increased the yield by 0.24-0.27kg/tree (Fig. 1). The usefulness effects of plastic mulches were also demonstrated in WUP, where one cubic meter of water consumption produced 22, 42 and 44 grams of dry product for control, black and white plastic mulch, respectively. This means the use of plastic mulch doubled the WUP. On the other hand, there were no significant differences between the white and black plastic mulches.

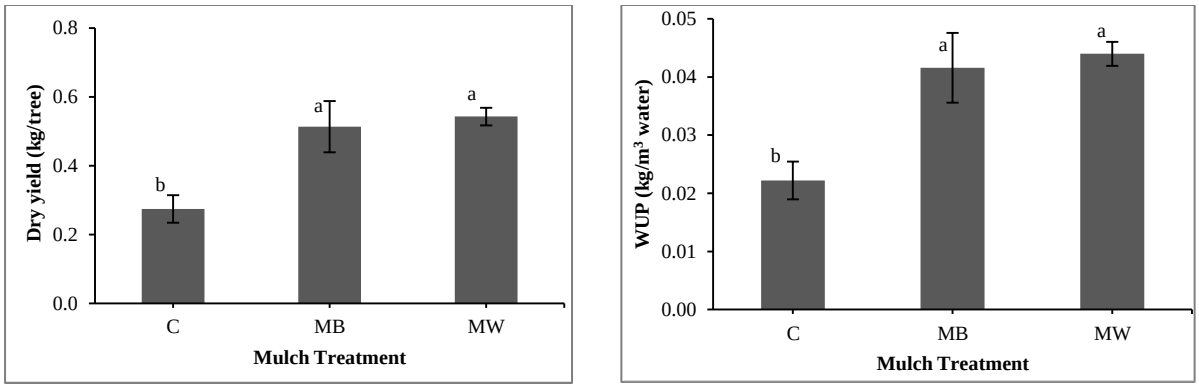


Fig.1. The effect of mulch treatments on the yield and WUPof Pistachio trees in orchard 1.

Orchard 2: Similar to the orchard one, white and black plastic mulch did not show significant differences in estimated parameters. The dry yield in mulch treatments were 0.6 to 1.1kg/tree higher than no mulch. As shown in Fig. 2, WUP increased in plastic mulch treatments 20%-36% compared to the control, where one cubic meter of water consumption produced 1.058, 1.265 and 1.439 kg/tree of dry product for control, black and white plastic mulch, respectively. In all traits, white plastic mulch was better than black one. However, the differences were not significant.

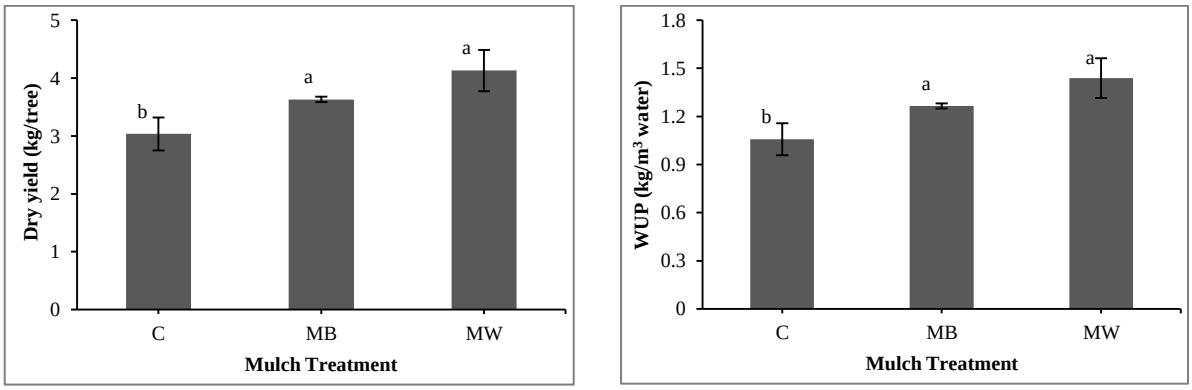


Fig.2. The effect of mulch treatments on the growth, yield and WUP of Pistachio trees in orchard 2

The effect of different treatmentson soil moisture content

Orchard 1: Fig. 3 showed the results of volumetric soil moisture contents from surface to a depth of 75cm in the root zone of trees in different treatments during July and August. According to Fig. 3, within one day after irrigation, minimal differences were observed in the soil moisture content in coated and uncoated treatments with plastic mulches. The maximum difference was 2.5% and in the depth of 50 to 75 cm below the surface. The volumetric soil moisture content of surface layer decreased about 1.5% in the control group compared to the plastic mulch treatments. As the irrigation time increased, the differences of soil moisture in the different layers increased between the plastic mulch treatments and the control. The difference in the surface layer due to sun exposure and soil evaporation was higher than the other layers.

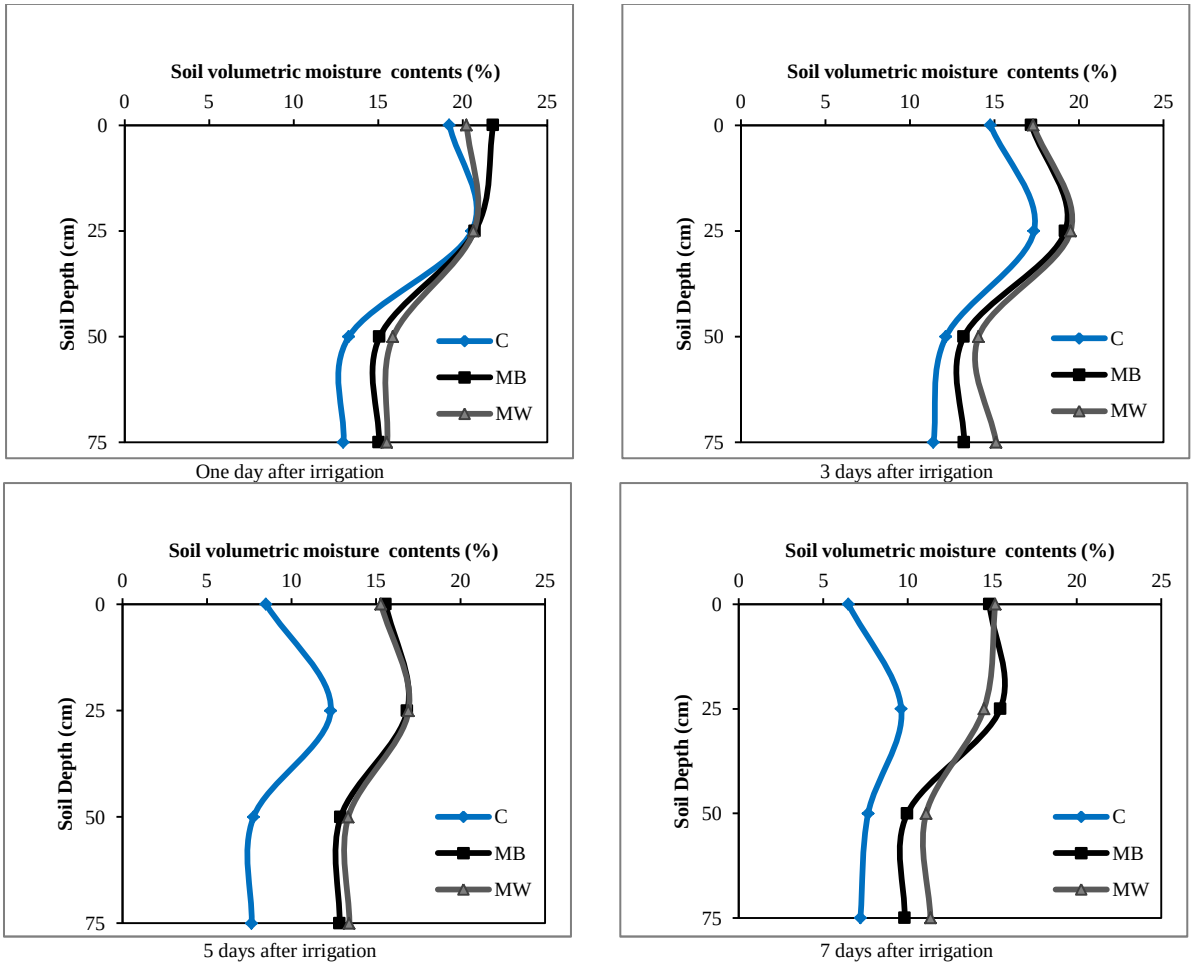
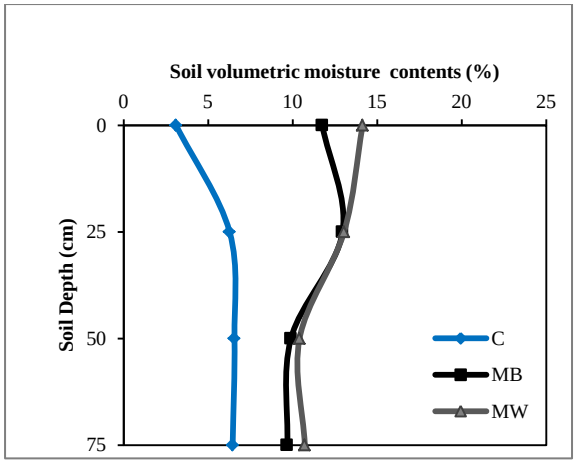
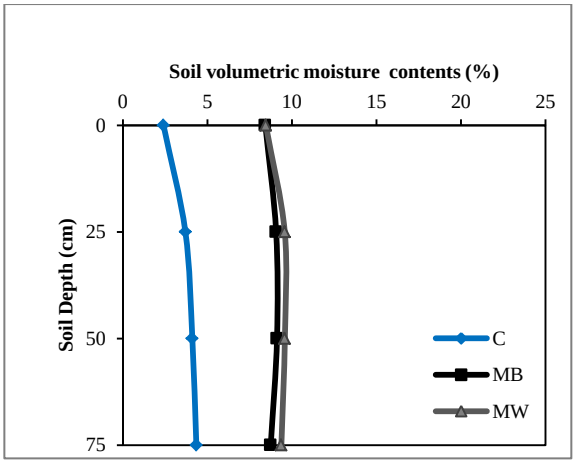


Fig. 3. The average changes in soil moisture content in different treatments between two consecutive irrigation in the orchard 1



9 days after irrigation

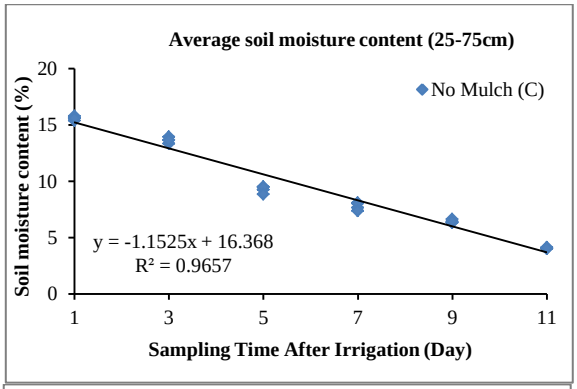


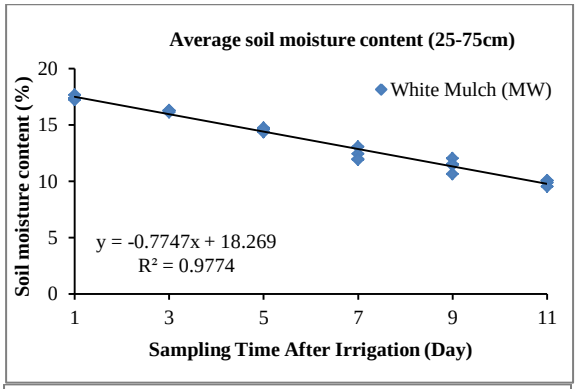
11 days after irrigation

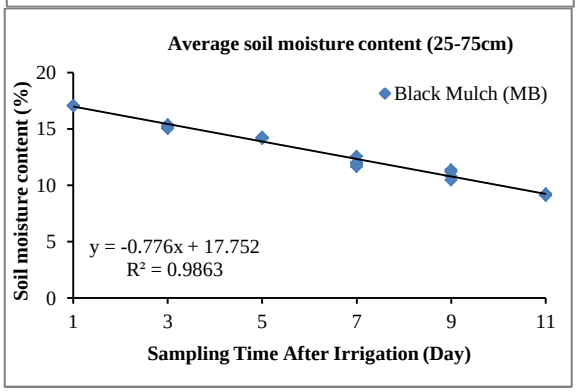
Fig. 3. Continued.

The highest differences of soil surface moisture in control and plastic mulch treatments were observed on the ninth day after the irrigation, which was 11%. After this time, the soil surface completely dried in the control group, while in the plastic mulch treatments, the soil moisture was reduced due to the absorption of water by the plant. At the end of the irrigation frequency, there was a 6% difference in the moisture of the whole soil profile between the control and mulch treatments. For loamy sand soil, the difference was significant. Considering that soil often pistachio orchards of Kerman province is sandy loam to loamy sand and the depth root density of pistachio trees in these soils is usually between 30cm and 80cm (Alipour and Hosseinifard, 2007). The highest water demand and evaporation occurs in July and August.

In order to determine when the soil moisture reaches the PWP and RAW in experimental orchards, linear regressions were calculated between the sampling times (after irrigation) and soil volumetric moisture data (Fig. 4).







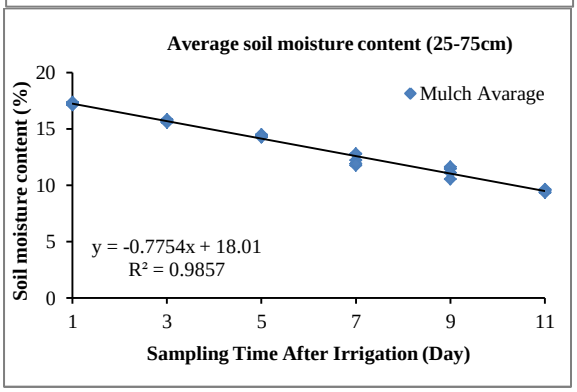


Fig. 4. The fitting equations of soil moisture content in different treatments between two consecutive irrigation in the orchard 1

The fitting equations of soil moisture content between two consecutive irrigations and estimated optimal irrigation frequency has been shown in Table 4. Based on the average soil moisture content in PWP and RAW at a depth of 25 to 75 cm, the following results were derived:

– Soil moisture in the root zone reached to the RAW and PWP after six and eight days in the control treatment, respectively. In the plastic mulch treatments, soil moisture content reached to RAW and PWP after 11 and 14 days, respectively.

– If you want to consume the total available water in the soil (soil moisture reaching the PWP) and accept some drought stress on trees, the irrigation frequency can be set at eight and fourteen days in July and August in the control group and mulch group, respectively.

Similar results between black and white plastic mulch were observed in all cases.

Table 4. Fitting equations of soil moisture content between two consecutive irrigation and estimation of appropriate irrigation frequency in the orchard 1

Mulch treatment	Fitting equations	Coefficient of determination (R^2)	Optimal irrigation frequency (day) according to:	
			RAW*= 9.4%	PWP=7%
No Mulch (C)	Y= -1.1525X + 16.368	0.9657	6.0	8.2
White Mulch (M_w)	Y= -0.7747X + 18.269	0.9774	11.4	14.6
Black Mulch (M_B)	Y= -0.7760X + 17.752	0.9863	10.7	13.9
Mulch Average	Y= -0.7754X + 18.010	0.9857	11.1	14.2

*RAW and PWP values relate to the average values of them in depth of the maximum root development (25-75cm).

Orchard 2: In this orchard, Figs. 5 and 6 showed the mean volumetric soil moisture contents that can be measured from surface to depth of 75 cm in the root zone of trees in different treatments in the interval between two consecutive irrigation.

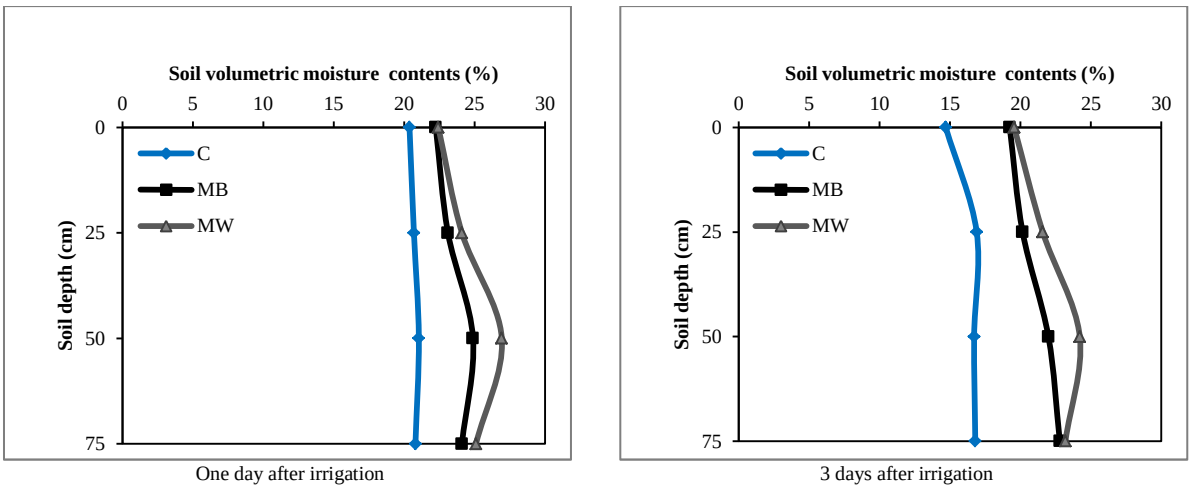
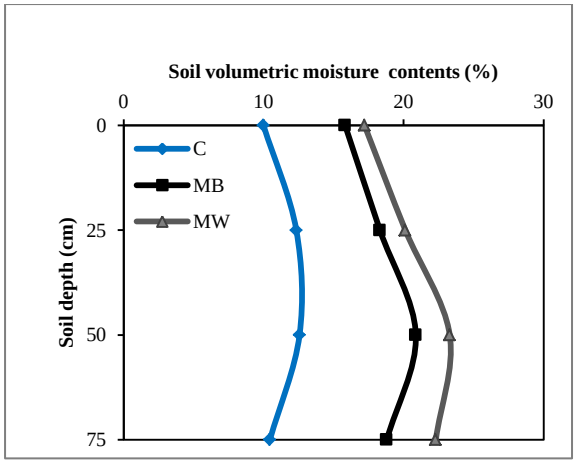
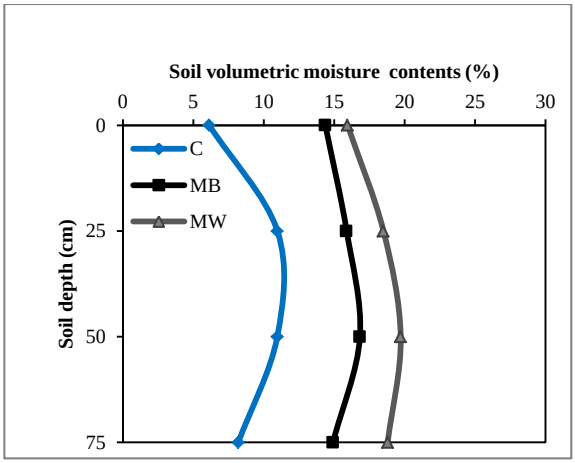


Fig. 5. The average changes in soil moisture content in different treatments between two consecutive irrigation in the orchard 2



5 days after irrigation



7 days after irrigation

Fig. 5. Continued.

According to Fig. 5, within one day after irrigation, the soil moisture content showed a greater difference compare to orchard 1 in plastic mulch and control treatments. The difference between the mulch and control treatments were 2% in the surface and maximum 6% in a depth of 50cm. Soil moisture curves in Fig. 5 showed that when it passed through the irrigation time, soil moisture differences in the different layers were higher in the treatments with and without plastic cover and moisture differences was about 12% at a depth of 75cm (Table 5).

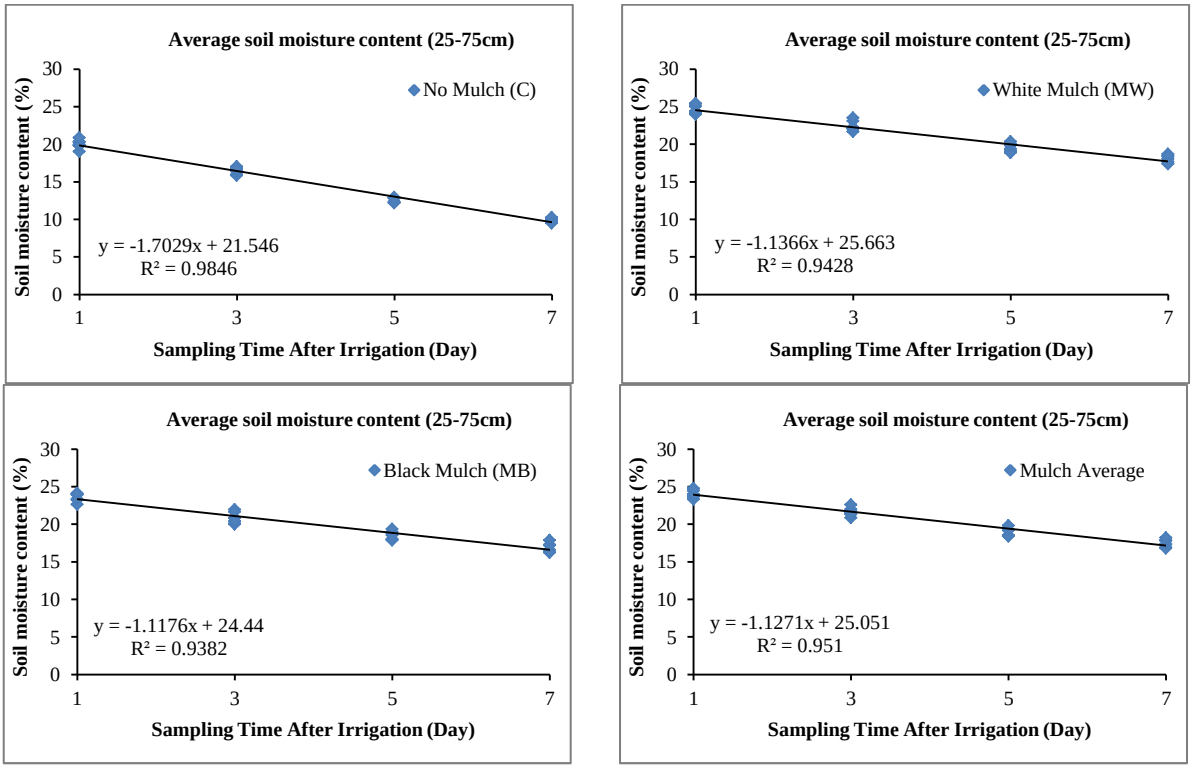


Fig.6. The fitting equations of soil moisture content in different treatments between two consecutive irrigation in the orchard 2

Table 5. Fitting equations of soil moisture content between two consecutive irrigation and estimation of appropriate irrigation frequency in the orchard 2

Mulch treatment	Fitting equations	Coefficient of determination (R^2)	Optimal irrigation frequency (day) according to:	
			RAW*= 11.2%	PWP=8.4%
No Mulch (C)	Y= -1.7029X + 21.546	**0.9846**	**6.1**	**7.7**
White Mulch (M_w)	Y= -1.1366X + 25.663	**0.9428**	**12.7**	**15.2**
Black Mulch (M_B)	Y= -1.1176X + 24.440	**0.9382**	**11.8**	**14.3**
Mulch Average	Y= -1.1271X + 25.051	**0.9510**	**12.3**	**14.7**

*RAW and PWP values relate to the average values of them in depth of the maximum root development (25-75cm).

Considering the average moisture content of the soil in PWP and RAW at the depth of 25cm to 75cm in this experimental orchard, the following important points were extracted:

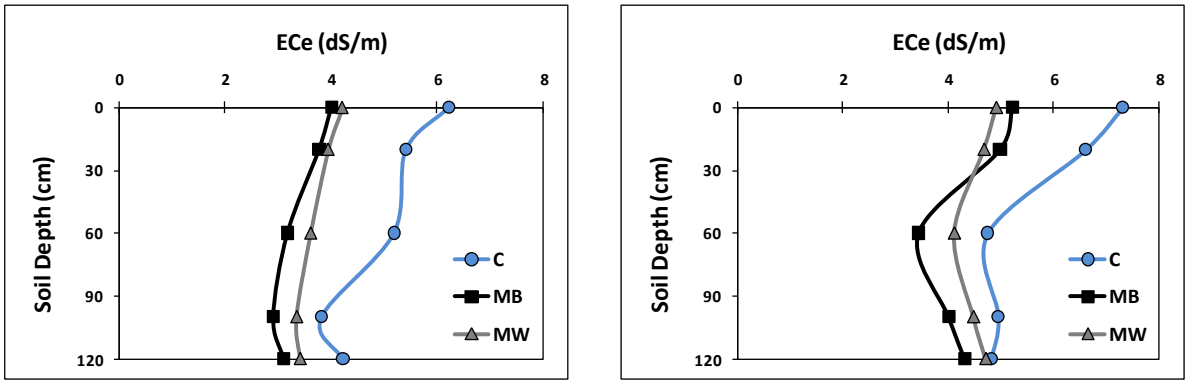
– The soil moisture in the root zone in the control group was reached after six days to RAW and after about eight days to PWP. The number of days to reach the soil water content in RAW and PWP in the treatment groups with plastic covers were about 12 and 15 days.

– If you use plastic mulch in this orchard, irrigation frequency is short and without stress on the trees, it can be increased up to 12 days.

– The results were similar between the black and white plastic mulchs.

The effect of different treatments on soil salinity

Orchard 1: Soil salinity changes in different treatments in two points of sampling, below emitter and at the end of the wetting front (distance of approximately 1 meter from the emitter), are shown in Fig. 7.



The below emitter — The distance of one meter from the emitter

Fig. 7. The soil salinity changes in different treatments in two locations of sampling in the orchard 1

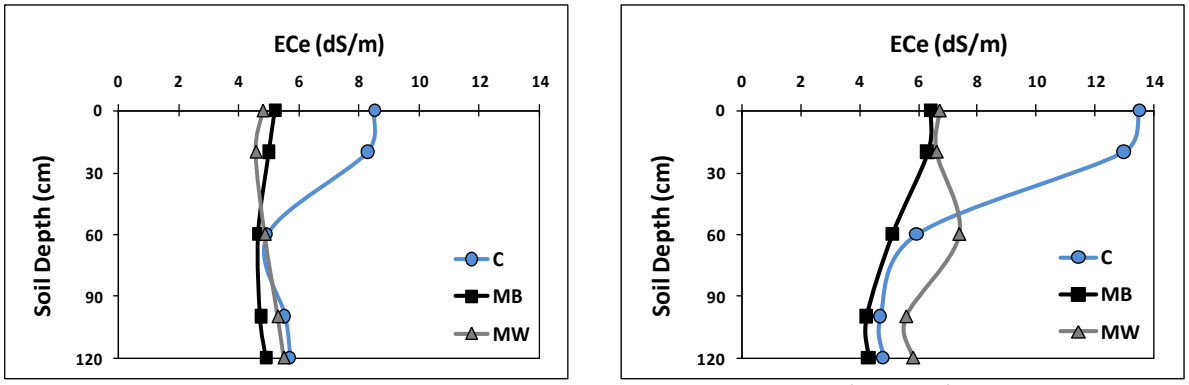
The results showed that use of plastic mulch decreased the salinity of the soil surface under emitter and the end of the wetting front, 2 and 2.5dS/m compared to the control treatment, respectively. The salinity difference was less in the lower depths. The total salinity of the soil profile improved in the treatments with plastic covers than in the control group. Another point is that in the plastic cover treatments, salinity changes beneath the emitter, from the soil surface to a depth of 120 cm, was very low and at a maximum of 0.7dS/m, that distribution is very good. The difference in salinity reached up to 2.4dS/m in the control group.

The results showed that the use of plastic mulch decreased the soil surface salinity in the control treatment under emitter and at the end of the wetting front to 33.9% and 30.8%, respectively. Plastic mulches affected the vertical distribution of soil salinity in under emitter. The average soil salinity of plastic mulch treatments (3.9, 3.4, 3.1 and 3.5dS/m) within the 0–40, 40–80, 80–120 and 0-120 cm soil depths

was 27.8, 34.6, 18.4 and 27.7% lower than that the no mulch treatment. The average soil salinity of plastic mulch treatments at the end of wetting fronts (4.9, 3.7, 4.3 and 4.3dS/m) was 25.7, 21.3, 12.2 and 20.4% lower than that the no mulch treatment group in different sampling depths.

Orchard 2: The results of soil salinity have been shown in Fig. 8. The results showed that soil surface salinity between treatment with and without mulches in the orchard 2 were higher than orchard 1. The soil surface salinity differences between treatments in both of sampling points reached to about 3.7dS/m in the beneath of emitter and 7 dS/m at the end of the wetting front. The salinity difference at the depth of 30 cm of soil surface was high and gradually decreased with increasing of soil depth. In both of sampling place, from depths of 60 to 120 cm, salinity in all treatments were similar.

Similar to orchards 1, plastic mulches had the same effects on vertical distribution of soil salinity. The decrement of soil surface salinity in plastic mulches were 41.2% and 51.8% lower than that the control treatment under emitter and the end of wetting front, respectively. Plastic mulches affected the reduction rate of soil salinity under emitter with an average 4.8, 4.7, 5 and 4.8dS/m within the 0–40, 40–80, 80–120 and 0-120 cm soil depths which was 42.2, 4.1, 9.1 and 22.6% lower than that the no mulch treatment group. The average soil salinity of plastic mulch treatments at the end of the wetting front (6.4, 6.2, 4.9 and 5.8dS/m) within the 0–40, 40–80, 80–120 and 0-120cm soil depths, that to the depths of 0-40 and 0-120 was 50.8% and 26.6% less than that the control treatment, and to the depths 40-80 and 80-120 was 5.1% and 4.2% higher than that the no mulch treatment group.



The below emitter The distance of one meter from the emitter

Fig. 8. The soil salinity changes in different treatments in two locations of sampling in the orchard 2.

Discussion

Overall, plastic mulches significantly increased yield production and WUP compared to the no mulch group by 0.24-1.1 kg/tree. The use of plastic mulch doubled WUP compared to the no mulch group. There were no significant differences between the white and black plastic mulches in yield and WUP. Several studies have shown the beneficial effects of mulches on quantity and quality of yield in different crops. For example, Peng *et al*. (2015) showed that the use of rice straw and branches of trees increased 37.4% and 40.6% yield of the pear trees, respectively. Similar results were obtained by Dinesh and Nazeer (2015) on the effects of plastic mulch to increase WUP in rainfed almonds in Pakistan. Pang *et al*. (2010) showed that plastic mulch combined with drip irrigation on the lemon tree increased the yield from 9 to 15kg/tree compared to the control group.

The results of volumetric soil moisture contents from surface to depth of 75cm in the root zone of trees in different treatments showed little differences within one day after irrigation in soil moisture content in coated and uncoated treatments with plastic mulches. As the irrigation time passed, the differences became

more pronounced in soil moisture in different layers between the plastic mulch treatments and the control group. The differences were more in the surface layer due to sun exposure and soil evaporation. A 6-12% difference was observed at the end of irrigation frequency in the moisture of the whole soil profile between the control and mulch treatments for loamy sand to sandy loam. Dinesh and Nazeer (2015) reported a significant increase in soil moisture during the growing season on almond trees by using plastic mulch. Kumar and Dey (2011) showed that the moisture conservation in the root zone of strawberry plant increased by 2.80%–12.8% under black plastic mulch as compared to the no mulch group.

Based on the average soil moisture content at the root zone of trees, RAW and PWP occurred after six and eight days in the control and 12 and 15 days in plastic mulch treatments, respectively. According to the 12 day irrigation frequency in orchard 1, in the treatments without mulch, trees of the orchard were under stress from the sixth day and after eighth day, water was not absorbed from the soil. Therefore, one of the main causes of poor growth trees in this orchard was long irrigation frequency. In orchard 2, after the sixth day, the trees became under partial drought stress and stop absorbing water from the soil without mulch treatments. Therefore, 8-day irrigation frequency the ideal time for sustaining good growth of trees.

The amount of water required in the other months of the growing season are less in July and August. Thus, irrigation frequency of 8 and 15 days should be used in the control group and mulch group, respectively.

In irrigation management, the selection of appropriate irrigation frequency was very important. The amount of used water in the orchard1was increased up to 50% compared to orchard 2, but due to the inappropriate choice of irrigation frequency in the orchard 1, the trees had undesirable growth.

Generally, plastic mulches decreased the total salinity of the soil profile under emitter and the end of the wetting front compared to the control treatment ranged from 30%-52%. The differences between salinity of plastic mulches and the control group were more pronounced in the soil surface. On the other hand, minimal changes were recorded in salinity from the soil surface to a depth of 120 cm in plastic mulches than control treatments, which indicates proper vertical distribution of salinity in soil profile. Higher differences have been recorded in soil surface salinity in orchard 2 compared with orchard 1. The soil texture and water consumption can be due to salinity differences. Bezborodov *et al* .(2010) showed that the salinity level of 15cm above ground increased 20% in the no mulch treatment group compared to the mulch treatment group. Differences among treatments with increasing soil depth were minimal and completely correspond to the results in this study. Research of Peng *et al.* (2010) showed that salinity in layers 0-20, 20-40 and in an average of 0-100cm soil depth, 10.2, 14 and 1.8% was lower than no mulch, respectively. A further reduction of soil salinity to 40cm soil surface layer was shown, which is consistent with our results.

Conclusions

The use of plastic mulch in drip irrigation systems of pistachio trees, in addition to a significant increase in pistachio production, doubled WUP compared to the control group. In both experimental orchards, significantly increased the soil moisture in the root zone of trees and reduced salinity and drought stress. Irrigation frequency increased two times compare to the no mulch/control group. Suitable irrigation frequency in pistachio trees with drip irrigation in soils with loamy sand to sandy loam, in July and August, for no mulch (control) and plastic mulch treatments recommended between six and eight days and between 11 to 15 days, respectively.

In irrigation management, considering the amount of irrigation water needed by tree, just not enough, and choose irrigation frequency depends on the soil texture and water holding capacity of the soil, is very important. Perhaps with less irrigation water and selection of suitable irrigation frequency, better results

can be achieved. Plastic mulch color had no significant effect on any of the parameters.

The use of plastic mulch, depending on the amount of consumption water, irrigation frequency, soil texture and sampling points, decreased the soil surface salinity from 30.8% to 51.8% compared to the control group. The average salinity of 0-120cm soil depth reduced from 20.4% to 27.7% compared to the no mulch treatment group. With increasing depth, soil salinity difference in treatments was reduced. The use of plastic mulch on lateral tubes, in addition to the reduction of the transport of salts to the soil surface due to water evaporation losses and reducing the capillary rise of water in the upper layers of soil, better leaching of salts in the root zone of maximum density allowed.)

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