APPLICATION OF BRACKISH WATER IN SUBSURFACE DRIP IRRIGATION SYSTEM ON PISTACHIO ORCHARDS

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ABSTRACT

Irrigation systems with higher efficiencies such as microirrigation systems are developing since last decade to achieve higher water use efficiency. At the same time, quality of water is decreasing in those areas due to overwithdrawal from the water resources. In Kerman province, the salinity of water increased to more than 10 dS/m in some area mainly due to water overwithdrawal. Therefore, application of saline water for irrigation of pistachio orchards is now inevitable, which contributed to increase in salt accumulation in soil surface and soil degradation. The main purpose of this study was the use of saline water in subsurface dripirrigation system (SDI) of pistachio orchards. The research was conducted during 2005-2008 on 12 year old pistachio trees. The drip-lines with self-cleaning and pressure compensating drippers were placed in two depths of 50 and 70 cm based on the fertilizer channel depth for pistachio trees. Emitters flow rate was 3.6 l/hr and 75 cm apart. Treatments consisted of two drip-line depths, and three irrigation levels of 100% (I_1), 75% (I_2) and 50% (I_3) of pistachio water requirements, with three replications, based on a completely randomized block experimental design. Salinity of irrigation water was 8.1 dS/m and irrigation water was applied in a 10 day - interval. According to the results, there was no significant impact of irrigation water treatment on pistachio yields. Annual applied irrigation water for I_1, I_2 and I_3 was 2050, 3065 and 4010 m^3/ha and water use efficiency of pistachio was 1.1, 1.2 and 2.0 kg/m^3 respectively. Pistachio quality characteristics improved compared with pistachio trees irrigation by a surface irrigation system. Salinity increased near the soil surface by decreasing in depth of drip-line setup.

1. Introduction

Pistachio is one of the agricultural crops in Iran which cultivate in arid and semiarid regions. Total area under pistachio in Iran is about 370,000 ha, from which 80% is located in Kerman province. Kerman province is located in south east of Iran with a dry climate. The main limitation for development of pistachio in this region is water resource. The irrigation interval of 120 days is reported for some farms. Accordingly, not only the water quantity but also the water quality in some part of province caused that pistachio orchard getting dry and disappeared. The salinity of irrigation water in some part of the

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region reached to more than 10 dS/m and even reached to 25 dS/m. The majority of irrigation system in the region is surface irrigation. It is while, most of the farmers changed the irrigation system to surface drip irrigation during the last decade.
Applying saline water continuously for irrigation through surface drip irrigation (DI) systems might result in salt accumulation close to the soil surface (Bresler et al., 1982; Ayers and Westcot, 1985; Pasternak and DeMalach, 1987; DeMalach and Pasternak, 1993; Oron et al., 1995). During irrigation or precipitation, the salts that are accumulated close to the soil surface can migrate downwards and reach the main root zone.
Salt accumulation may inhibit water and nutrient uptake, consequently affecting the crop growth and yield (Hanson, 1995). In order to offset the osmotic shock imposed on the crop by the leached salts, a practical solution was proposed. It was suggested to further leach the accumulated salts in the main root zone to deeper layers by continuing to drip irrigate simultaneously with the periods of precipitation. The chemical clogging is another issue in surface drip irrigation system when we are using saline water. In Kerman region, most of the farmers who cannot save his water during the winter, applying one or two surface irrigation to leach out the salt from top soil layer and save some water in surface profile for spring as well.
Alternatively, Oron et al. (1990) and Phene et al. (1990) have proposed that this problem can be overcome by applying saline water through a subsurface drip-irrigation (SDI) system, if it manages properly. It is anticipated that under SDI, the salt front is partially driven down into the deeper soil bulk media and to the periphery of the root zone, thus minimizing the risk of damaging the main roots of the plants. Moreover, the improved moisture conditions in the vicinity of the emitter offsets the inhibiting effects of the presence of the salts in the saline water (Michelakis et al., 1993). Additionally, Phene et al. (1987) reported that since the SDI is installed below the soil surface, a properly managed system can increase the advantages of the system compare to surface drip irrigation, especially in the areas of efficient water and nutrient utilization, salinity management and deep percolation. Subsurface drip irrigation system could also benefit to decrease the emitter clogging.

The purpose of this study is to verify the effect of SDI with emitters located at two depths in the soil and of applying different water qualities, on the soil moisture, salinity distribution in the soil profile, and eventually the crop yield.

2. MATERIAL AND METHODS

2.1. The experimental site

Kerman province located in south of Iran is the main agricultural region of the country for pistachio production. The annual potential evapotranspiration in this region is more than 3000 mm, where more than 95 percent of pistachio orchards are irrigating traditionally with an efficiency of less than 40%. It is while, evaporation and deeper collation in traditional irrigation system (surface irrigation) is significantly high.
The on-going experiment is being conducted in a private farm in Akbarbad Zandi village, located about 135 km southwest of the city of Kerman, Iran. The mean annual rainfall in the region is 102 mm. Mean maximal ambient temperature reaches about 34.98C during July and August, and mean minimal temperature is close to 5.48C during January. The relative humidity during the summer months varies from 20 to 30%. Annual, class `A' pan evaporation is more than 3000 mm. The experimental soil is considered as a sandy loam, a uniform profile, consisting of 51.4% silt, 8.8% clay and 39.8% sand.

2.2. The experimental layout

The possibility of using SDI for saline-water application was examined in a pistachio orchard (Fig. 1). The pistachio trees, arranged in 18 rows, each six as one replication. Six trees were selected in each row for data collection. Two drip laterals served every pistachio row, with emitters spaced 0.75 meter apart and having a discharge of 3.6 l/h. prior to commencement of the experiment, the trees were irrigated by surface irrigation. The research began in March 2004 for 4 years. The experiment consists of the following treatments in each replication:

1. Three irrigation depth based on 100% (I1), 75% (I2) and 50% (I3) of pistachio trees water requirement
2. Two depth of drip line located at 50 and 70 centimetre

Same saline water having a EC of 8.1 dS/m applied in all treatments with an irrigation interval of 10 days.

2.3. Moisture and salinity monitoring in the soil

Soil-moisture and salinity distributions in the soil at different depths and locations, as related to the emitters and the tree trunk in every treatment, were monitored periodically, following standard procedures 2 or 3 times each year. Soil-moisture content was measured by a standard soil sampling method. The soil salinity in the root zone was expressed by the electrical conductivity of the saturated soil extract, ECe. Soil samples for moisture and salinity assessment were taken at 1m from lateral and between two trees along the row. The corresponding depths were 0-40, 40-80, and 80-120 cm. The pistachios were hand harvested during September of each year.

Figure 1. Schematic description of saline-water use experiment under drip irrigation in the pistachio orchard.

2.4. Water Productivity

In agricultural production systems, crop water productivity (WP) accounts for crop production per unit amount of water used (Molden, 1997). The numerator maybe expressed in terms of crop yield (Kg ha^{-1}). When considering this relation from a physical point of view, one should consider transpiration only as denominator. However, the partitioning of evapotranspiration into evaporation and transpiration in field experiments is difficult and therefore not a practical solution. Based on Molden (1997), a number of options are available to define the volume of water per units of area (m^3 ha^{-1}) in the denominator, i.e. transpiration, evapotranspiration (ETc), applied water (I), water diverted, water beneficially consumed, and water beneficially and non-beneficially consumed. We used following definitions of crop WP;

$$WP_I \text{ (kg m}^{-3}\text{)} = \frac{\text{Ya(kg)}}{\text{I(m}^3\text{)}} \qquad (1)$$

Actual yield (Ya) is defined as the marketable part of the harvested pistachio.

3. RESULTS AND DISCUSSION

3.1. Water application

During the four experimentation years, all treatments received annual equal volumes of irrigation water amounting to approximately 736 mm (Table. 1). Water application commenced towards the early April and continued up to November. Irrigation interval was fixed for 10 days due to the water allocation system and just irrigation time increased by crop development stage. During the peak period of consumption (July to August), the irrigation time increased to about 26 hrs for I1 in order to maintain adequate soil moisture in the effective crop root zone. Irrigation scheduling was based on Class `A' Pan Evaporation measurements, multiplied by the locally developed crop coefficients for pistachio plantations.

Table 1. Daily crop water requirement and irrigation time for irrigation treatments during irrigation season

Irrigation time (hr) for 10 days interval			Daily irrigation requirement (L/day)	ET_C (mm/day)	Days	Month
I3	I2	I1				
5.2	7.7	10.3	16.5	1.76	1-10	April
5.8	8.6	11.5	18.4	2	11-20	
6.3	9.45	12.6	20.2	2.19	21-29	
6.85	10.27	13.7	21.9	2.38	1-11	May
7.75	11.6	15.5	24.8	2.69	12-21	
8.94	13.41	17.88	28.6	3.11	22-31	
10.34	15.51	20.68	33.1	3.59	1-10	June
11.75	17.6	23.5	37.6	4.08	11-20	
11.45	18.6	24.75	39.6	4.3	21-30	
12.9	19.35	25.8	41.3	4.48	1-10	July
13.1	19.7	26.25	42	4.56	11-20	
12.7	19.1	25.43	40.7	4.42	20-31	
12.3	18.5	24.63	39.4	4.28	1-10	August
11.9	17.85	23.8	38.1	4.14	11-20	
11.2	16.8	22.38	35.8	3.88	21-31	
10.44	15.66	20.88	33.4	3.62	1-10	September
9.6	14.4	19.18	30.7	3.33	11-20	
8.45	12.7	16.9	27	2.93	21-30	
7.2	10.8	14.38	23	2.5	1-10	October
6.1	9.1	12.13	19.4	2.11	11-20	
5.1	7.65	10.2	16.3	1.77	21-31	
3.2	6.3	8.43	13.5	1.46	1-10	November
3.4	5.1	6.75	10.8	1.17	11-20	
3.4	5.1	6.75	10.8	1.17	21-30	
206.32	**310.85**	**414.3**				

3.2. Moisture distribution in the soil

Spatial soil-moisture distribution in the soil was monitored by sampling, approximately 10 h after terminating the irrigation shift. The amount of water applied prior to monitoring varied, according to season, between 11.7 to 45.6 mm/10days.

3.3. Salinity distribution in the soil

Salinity distribution in the soil as expressed by the ECe also exhibits trends similar to that of the soil moisture. For the emitters located 50 cm deep the salinity trend is presented in Fig. 2. Accordingly, high soil salinity (8.1±11-19 dS/m) was recorded for different irrigation management. Less applied caused increase in ECe which attributed to less salinity leaching out. On the other hand, soil water absorption by crop and soil surface evaporation increased salinity concentration in root zone area.
According to the Fig. 2, moisture profile for each case examined, it can be concluded that SDI maintains continuous soil leaching not only downwards, but also upwards and radially. Primarily for emitters located at a depth of 50 cm, the soil salinity ECe in the main active root zone was in correlation with the salinity of the applied water. Extra leaching is thus required to shift the salt front into deeper soil layers.

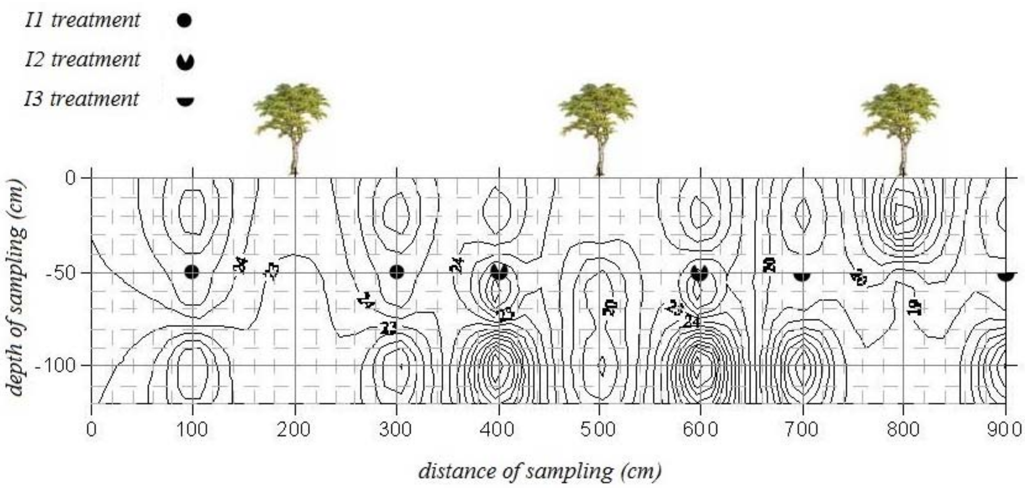

Figure 2. Salinity distributions, ECe, in the soil in a pistachio orchard under saline-water subsurface drip irrigation as a function of emitter depth (50 cm below the soil surface)

3.4. Yield

According to the field results, highest pistachio yields obtained when 100% of crop water requirement were applied but differences between the treatments was not significant (Fig 3). Accordingly, the yield of treatments when the emitters located at a depth of 50 and 70 cm below the soil surface was almost similar (1.6 ton/ha). This indicated that may trees received the required water from deeper soil layer where winter water was stored. An extended experimental and monitoring period is required in order to define trees transpiration water compared to the irrigation water and leaching amount. The yield was not much higher than average yield in the region but the irrigation water was much less. However, the yield has increased by year when the tree may adapted by SDI. The yield increased in last year for experiment to 7978 ton/ha which was almost 5 time of average yield in the site.

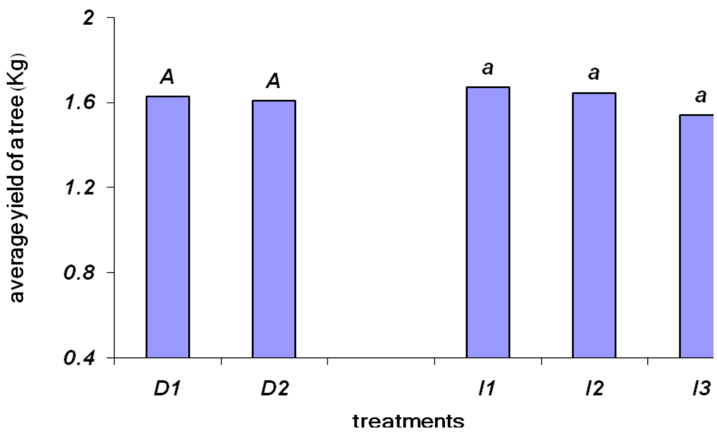

Figure. 3. Pistachio yield under different irrigaiton treatment (I1, I2, and I3) and location of emitter under the soil surface (D1 and D2)

3.5. Pistachio water productivity

Appling three levels of irrigation water; I1, I2 and I3, pistachio water productivity was calculated (Table 2). Accordingly, the highest level of water productivity (3.3 kilogram pistachio per a cubic meter of applied irrigation water) was measured when 50% of crop water requirement was applied for irrigation.

Table 2. Pistachio water productivity (kg/m3) for different irrigation treatments

	Year			
Treatment	1383	1384	1385	1386
I1	0.6	1.7	0.5	1.7
I2	0.7	1.7	0.6	2.1
I3	1.0	2.4	1.1	3.3

4. CONCLUSION

The possibility of using saline water through SDI for fruit trees irrigation is being examined in the field in a pistachio orchard in an on-going field experiment. Accordingly, impact of three irrigation treatments and emitter location under the soil surface on yield and salinity of soil were studied. As a result, by increasing emitter location depth in the soil, salt accumulation increased between the emitter and soil surface. There was not emitter clogging due to the root even though non kind of root-guard chemical material was used. The pistachio yield has increased by time (years) maybe because of trees adaptation to subsurface drip irrigation. The emitter's location under soil surface between 50 and 70 was not effective to trees yield. Annual applied irrigation water for I1, I2 and I3 was 2050, 3065 and 4010 m^3/ha and average water productivity of pistachio was 1.1, 1.2 and 2.0 kg/m3 respectively. Based on the above conclusions, subsurface drip irrigation was recommended to pistachio orchards where salinity of irrigation water is not higher than 8 dS/m and study on higher salinity is recommended.

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