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ORIGINAL ARTICLE

Assessment of Soil wetting front subsurface drip irrigation of Pistachio

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ABSTRACT

This study was carried out to investigate the distribution of soil wetting front subsurface drip irrigation of pistachio in the region Safaieh of Semnan province from 2013 to 2014 years. This research was conducted in a 10 years old 2 hectares pistachio garden. Distance of trees was 3 meters in rows and 7 meters between rows. Subsurface drip irrigation with drip tube installation depth of 40 cm was used. So that each row and each tree included two lateral and each lateral were installed in 1 meter distance. Subsurface drip irrigation system were investigated through an experiment with 3 irrigation regimes, 3 sampling depths, time (before and after irrigation) and time after the first irrigation using split plot factorial design Simulation was performed by HYDRUS-2D software. Evaporation rate and the total evapotranspiration were considered as zero and transpiration, respectively. The results showed that of water consumption in irrigation regime I_2 which was achieved by daily meteorological data was better and more successful in terms of leaching and distribution of moisture. The correlation coefficient between 0.57to 0.90 demonstrated a good prediction model HYDRUS-2D in the field.
Key words: Leaching, pistachios, irrigation regime, Semnan, HYDRUS-2D model

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INTRODUCTION

Generally, the use of irrigation systems with high efficiency, such as drip irrigation, is suggested as a basic solution to the problem of water shortage and its optimal usage. But drip irrigation system should be designed in such a way that water is distributed uniformly across the farm, in the root area. Foe achieving this, we should be well informed about the distribution of water in the appropriate soil. For this reason, analytic models have been created that can give and acceptable estimate of moisture in the soil, by having the hydraulic characteristics of the soil, and using equations of water movement in the soil [1]. Bristo *et al* [2] maintained that for designing and managing drip irrigation systems we need to be aware of the distribution of moisture and nutrients. This is possible by numerically solving the equations governing flow.

Li *et al*. [3] analyzed the distribution of moisture front in drip irrigation system for both soft soil and sand. The shape of moisture distribution in vertical and horizontal cross section can be shown using exponential functions. They used a function for water flow that with flow increase, the horizontal distribution of moisture increases and with flow decrease, the vertical distribution of moisture increases. Patel and Rajput [4] indicated that in sandy soil, with a flow rate of 2 liters per hour, the soil moisture for installation depths of less than 30 cm from the surface was more than 18%, and the breadth of wetness was about 60 cm, and for installation depths of 20 and 30 cm below the soil surface the most amount of moisture, usable at depths of 30, 45, and 60 cm, was gathered. Acker *et al.* [5] performed a study on loamy soil and noticed that different volumes of irrigation had a significant effect on the depth of the wetting front, but not on the radius of spread. In general the results showed that the intensity of spreading in drip irrigation system causes greater expansion of water and increases the volume of the moisture front.

In drip irrigation, for obtaining the arrangement of laterals and calculating the distance between them and the distance between the emitters, sufficient information about the distribution of moisture in the soil should be given to be able to determine a suitable distance for uniform water distribution, and the plant can grow in the best possible conditions regarding available water. If a subsurface drip irrigation system is used, the installation depth is added to the above items. Hence, the distribution of moisture in the soil is evaluated with various flow rates and installation depths, in order to obtain a good estimate of the shape of the moisture front and the plant's response to the available conditions. If the dimensions of the moisture front are less than adequate, the plant cannot absorb enough water and this causes a decrease in its performance. In addition to this, the dimensions of the moisture front causes the root system not to expand sufficiently, and the farmer is forced to keep the moisture level high in the wet areas, using repeated watering [6]. The depth of installation of subsurface lines is affected by the type of plant, type of soil, climate, and farm operations; but this depth varies between 2 and 70 cm. Batam *et al.* [7] expressed that the moisture pattern around the emitters can be an indicator for determining the depth of the lines in the system. Thourbon *et al*. [8] also obtained similar results, and suggested an installation depth of 40 and 60 cm for sandy and other types of soil. Bengall *et al.* [9] analyzed the effect of the texture of the soil on moisture distribution in subsurface drip irrigation system. Their results showed that with a flow rate of 0.719 meters per hour, and an installation depth of 40 cm, water appeared on the surface of loamy and clay soil in 8 hours and in 45 minutes respectively, but no water appeared on the surface of sand-loamy and sandy soils.

Analysis of sources regarding moisture distribution in subsurface drip irrigation system indicates that expansive research has not been performed in this area, and not all effective matters have been analyzed. Based on this, in this study, the distribution of moisture in a subsurface drip irrigation system in a pistachio farm is analyzed.

MATERIALS AND METHODS

This study was performed during 2013-2014 in Safaiyeh region of Sorkheh city in Semnan province. The study was performed in a 2-hectare pistachio farm with an estimated age of 10 years. The distance between trees in each row is 3 meters and the distance between the rows is 7 meters. A drip irrigation system, with an installation depth of 40 cm was used, such that there are two laterals (each at a distance of 1 meter from the tree trunk). The period of simulation of water absorption by the pistachio plant was 144 days, from the middle of the expansion period to the middle of the ending period. This period was from May 31st, 2013 to Oct. 21st, 2013.

Results of soil analysis showed that the soil under study has loamy-sandy structure. Characteristics of the soil under study are given in Table-1.

Table-1: Soil characteristics

Layer depth (cm)	texture	Clay (%)	Sand (%)	Silt (%)	Apparent specific weights (gr/cm^3)	Field capacity (%)	Wilting point (%)
0-25	Sandy loam	6	81	13	1.62	11.85	4.39
25-50	Sandy loam	4	77	19	1.56	11.97	5.12
50-75	Sandy loam	4	81	15	1.55	12.88	5.52

The amount of farming moisture capacity in each layer was obtained by placing samples of saturated soil from each layer in the pressure cell, and adjusting the pressure to 1/3 Bars (a suction of 0.3 atmosphere).

Since the evaporation component cannot be separated from the transpiration for the trees, and since moisture does not reach the surface of the soil due to using subsurface drip irrigation system, for the 144 days that simulation was done using the HYDRUS-2D software, the rate of evaporation was assumed to be zero and the total evapotranspiration was considered to be equal to the transpiration. Hydraulic guiding of saturated soil (Ks) was obtained using ROSETTA software as 91.14, 87.67, and 93.32 cm per day, for layer 1 (0-25 cm), layer 2 (26-50 cm) and layer 3 (51-75 cm), respectively. In table 2, characteristics of water of wells #1 and #2 is given.

For measuring moisture according to growth periods of the plant (Initial period, Development period, Midseason, and Late season) samples of soil before and after irrigation was taken using drilling. Generally, for measuring the moisture and the saltiness in every irrigation pattern, samples were taken from sampling locations (d_1, d_2... d_{15}=1, 2... 15) in three depths (0-25, 26-50, 51-75 cm) before and 24 hours after irrigation over the periods of growth of the plant.

Sampling the soil between the two laterals pertaining to row of trees:

In the row of trees (tree row 1) between two laterals (1 and 2) in the middle of two trees (with a distance of 1.5 m from the tree trunk) and at 30 cm from each lateral, 2 pits with a diameter of 50 cm was hollowed out by drilling equipment connected to a tractor. Samples were taken from the two walls of this pit at depths of 25, 50, and 75 cm, for measuring the moisture.

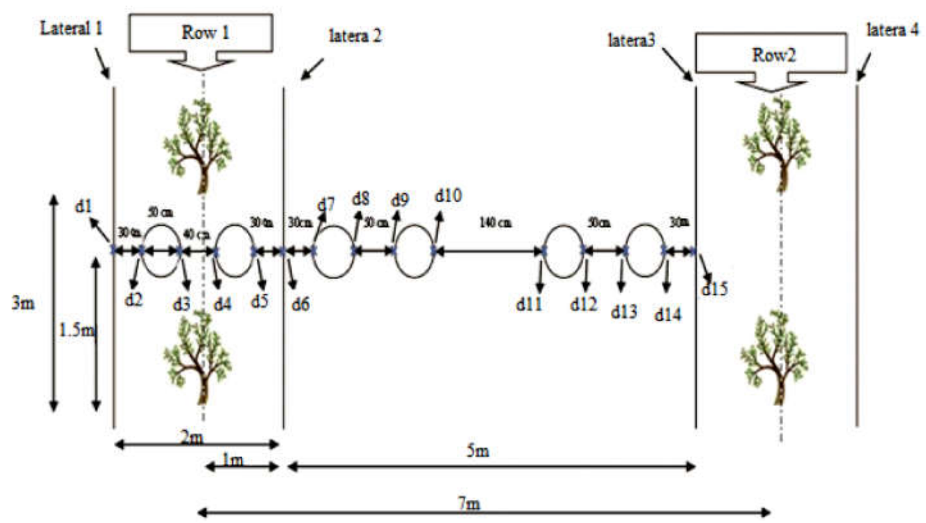
Table 2: Chemical and quality specifications of the irrigation water

Indexes	Wells No.1	Wells No.2
Na (meq/l)	42.2	24.18
Ca (meq/l)	27.21	26.35
Mg (meq/l)	17.89	16.85
K (meq/l)	0.62	0.51
Ca+Mg (meq/l)	45.10	43.2
Total cations (eq/l)	87.92	67.89
Co_3^{2-} (meq/l)	–	–
Cl^- (meq/l)	49	27.5
Hco_3 (meq/l)	2.25	2.65
So_4^{2-} (meq/l)	35.9	37.1
Total anions (meq/l)	87.1	67.2
EC_{iw} (dS/m)	7.9	6.1
pH	7.16	7.17
pH_c	6.8	6.7
SAR$(mmol/l)^{1.2}$	8.9	5.2
SAR_{adj}	23.1	13.8
TDS (mg/l)	5070	3890
LSI	0.361	0.432

Sampling the soil on the laterals

According to figure 1, on laterals number 1, 2, and 3, at a distance of 1.5 m from the tree trunk (toward the next tree in the same row), at depths of 25, 50, and 75 cm, soil samples were taken for measuring humidity and saltiness. Considering the depth of installation of the laterals (which was an average of 49 cm), in the event of running into a lateral, its vicinity was hollowed out carefully, and dug deeper to reach the desired depth for sampling.

Figure 1: Locations of sampling



○: Pits dug by drilling equipment (50cm diameter)

×: Locations of manual sampling (at depths of 25, 50, and 75 cm from the surface)

d_1=1, d2=$_2$, ... d_{15}=15 -25 cm -50 cm -75 cm below the surface for drawing curves of equal humidity, Golden surfer8 software was used.

Sampling the soil outside the laterals of tree rows

Outside laterals 2 and 3 (toward the side row of trees), in the orientation of the center of two tree trunks, two pits with diameter of 50 cm, at a distance of 30 cm from each lateral 2 and 3, was dug by drilling equipment. From the walls of the pit (the walls from the laterals side are shown by *), at depths of 25, 50, and 75 cm, the soil was sampled (the distance between the center of the pit and the lateral is 55 cm). Then at a distance of 50 cm each of the pits (the distance between the wall of the current pit and the wall of the new pit), a new pit is hollowed out by drilling equipment, and again, at depths of 25, 50, and 75 cm, the soil was sampled.

In general, according to figure 1, 6 pits with diameters of 50 cm were dug in locations marked by a circle, and from the walls of the pit (marked by x) at depths of 25, 50, and 75 cm, the soil was sampled for measuring humidity and saltiness. And, on laterals 1, 2, and 3 (shown by x), at the three depths, soil was sampled.

Three irrigation patterns were applied in the farm, as follows:

1- Irrigation pattern I_1 – Irrigation according to the common traditional method.
2- Irrigation pattern I_2 – Irrigation based on water need.
3- Irrigation pattern I_3 – Irrigation based on irrigation needs.

Uniformity of water distribution (Eu) The Carmel and Keller equation (1975) was used.

$$\mathrm{Eu} = 100 * \left[1 - 1.27\left(\frac{\mathrm{V}}{\sqrt{\mathrm{Np}}}\right)\right]\frac{\mathrm{qmin}}{\mathrm{qa}} \quad \text{(Equation 1)}$$

Eu:	Uniformity of water distribution (%)
V:	Coefficient of emitters
Np:	Number of emitters from which a tree receives water.
Qmin:	The minimum rate of the emitters (1/hr)
Qa:	Average rate of emitters (1/hr)

RESULTS AND DISCUSSION

In order to analyze the advancement of the moisture front, before and after irrigation, in three irrigation patterns, over the development, midseason, and end of season of pistachio growth in the development season, the surfer 8 software was used. Its results are shown in figures 2 through 7, all of which are drawn in the region between lateral 1 and 2 (according to figure 1). The horizontal axis denotes the distance from the trunk of the left tree (figure 1) (in fact, 0 is at the trunk of the tree), and the vertical axis denotes the depth of sampling, and the circles (at a depth of 40 cm) indicate the location of the emitters. The I_1 irrigation pattern denotes the common traditional method. The I_2 irrigation pattern based on water need (the penman monteith method – PM), and I_3 irrigation pattern is based on irrigation need. (PM+LR).

To analyze the advancement of moisture and water distribution before and after irrigation, during the growth development period, the 25th and 26th of June (97 and 98 days after the first irrigation) – as representative of this period, were selected and sampled. As shown in Figures 1 and 2, the maximum amount of moisture after irrigation is around the lines in the installation location of the emitters; and the amount of moisture below the emitters is more than above them. These results match the results by [10, 11].

In Figure 2 we see that among the three irrigation patterns studied, the maximum amount of moisture belongs to I2 (irrigation pattern based on water need (the penman monteith method – PM), and third was I_3 (irrigation pattern is based on irrigation need (PM+LR)), which are almost similar. Considering that the rate of moisture in the farming capacity of the soil under study is about 12% (volume), in I_1 before irrigation we notice a lack of irrigation. Even 24 hours after irrigation, we notice this phenomenon between two emitters. The amount of moisture in the other two patterns is at an adequate level (Figure 3).

To analyze the advancement of moisture and water distribution before and after irrigation, during the midseason growth period, the 18th and 19th of August (151 and 125 days after the first irrigation) – as representative of this period, were selected and sampled. As shown in Figure 4, in all three irrigation patterns, the moisture before irrigation is higher than the farming moisture capacity, which shows largeness of the hours of irrigation in all three irrigation patterns. These results show that the penman-monteith equation and the FAO crop coefficient overestimate the irrigation needs. And, during this period, a constant moisture profile between emitter lines (for forming uniform and sufficient moisture between emitter lines) was formed in all three irrigation patterns that indicates that the distance between these lines is adequate. And this is true for the first pattern, but with low humidity that does not satisfy

the needs of the plant. But in patterns 2 and 3 (I_2: Irrigation based on water needs according to the penman-monteith method (PM); I_3: Irrigation based on irrigation needs (PM+LR)) an adequate profile was created.
During this period, the maximum moisture belongs to I_3, and the minimum moisture belongs to I_1.
According to Figure 5, the highest amount of moisture was in the third regime.

Figure 2: Distribution of moisture percentage (by volume) before irrigation, June 25th (97 days after the first irrigation) in three irrigation patterns

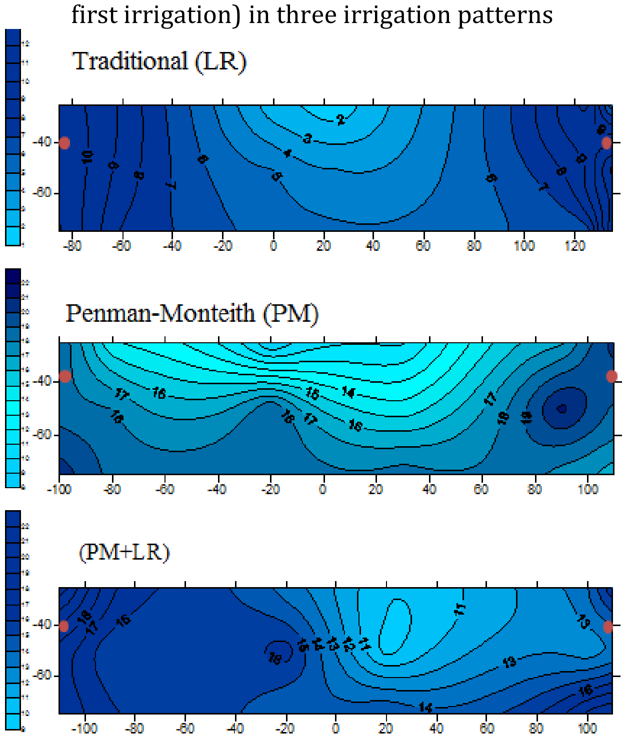


Figure 3: Distribution of percentage of moisture (by volume) after irrigation, June 26th, (98 days after the first irrigation), in three irrigation patterns

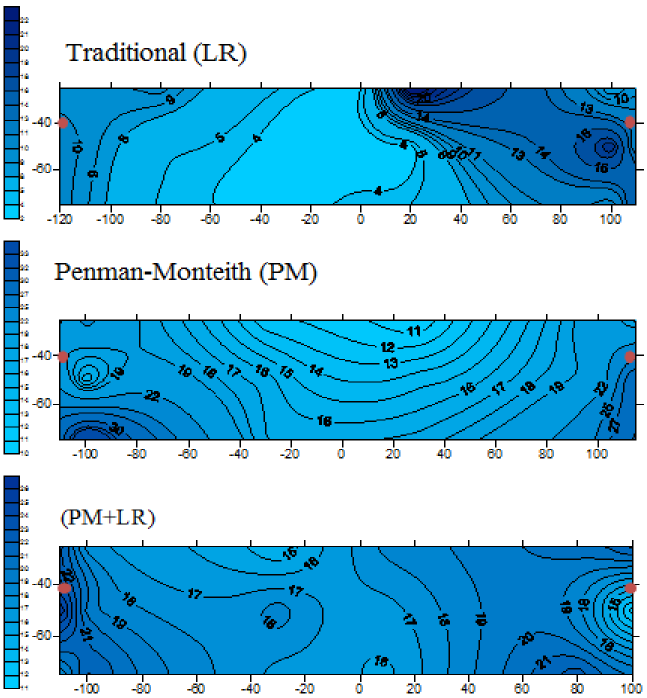


Figure 4: Distribution of percentage of moisture (by volume) before irrigation, August 18th, (151 days after the first irrigation), in three irrigation patterns

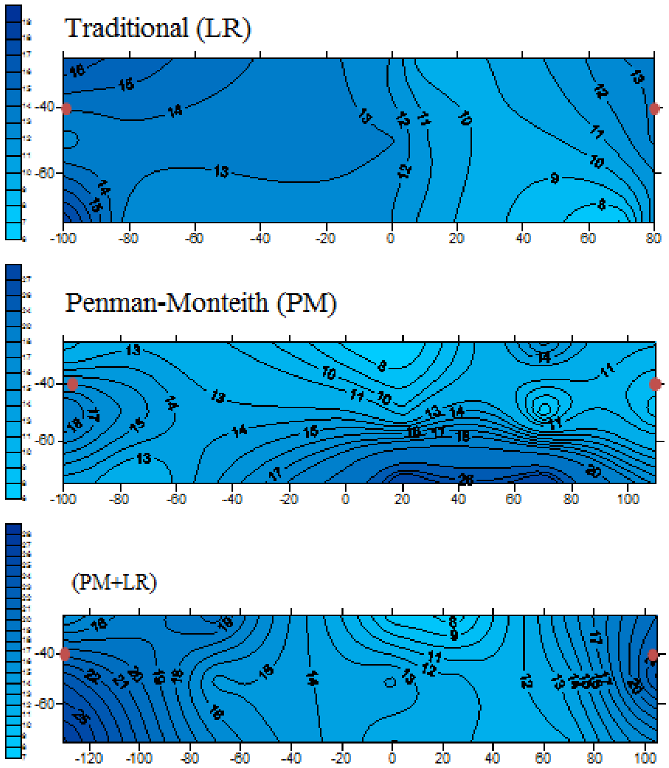


Figure 5: Distribution of percentage of moisture (by volume) before irrigation, August 19th, (152 days after the first irrigation), in three irrigation patterns

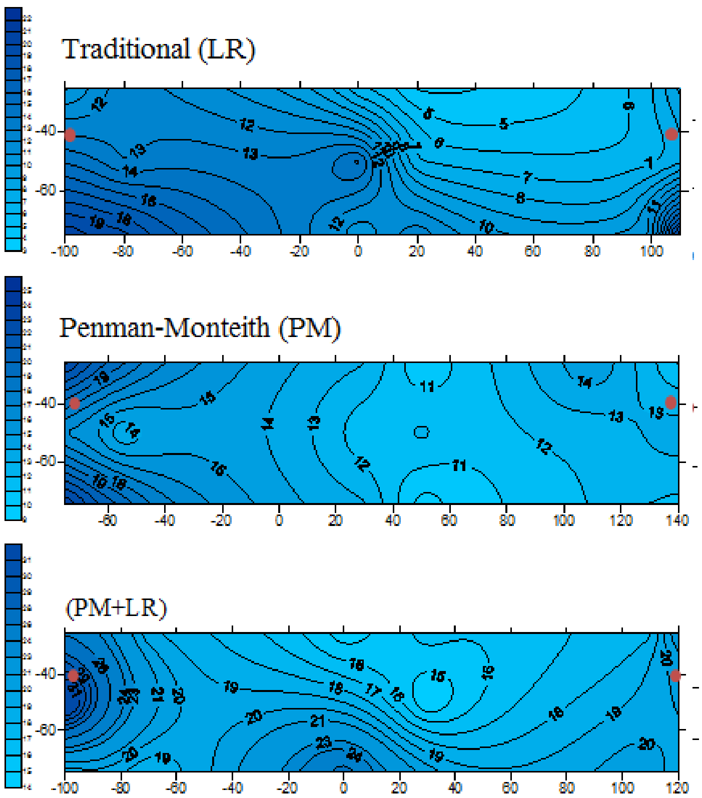


Figure 6: Distribution of percentage of moisture (by volume) before irrigation, October 14th, (207 days after the first irrigation), in three irrigation patterns

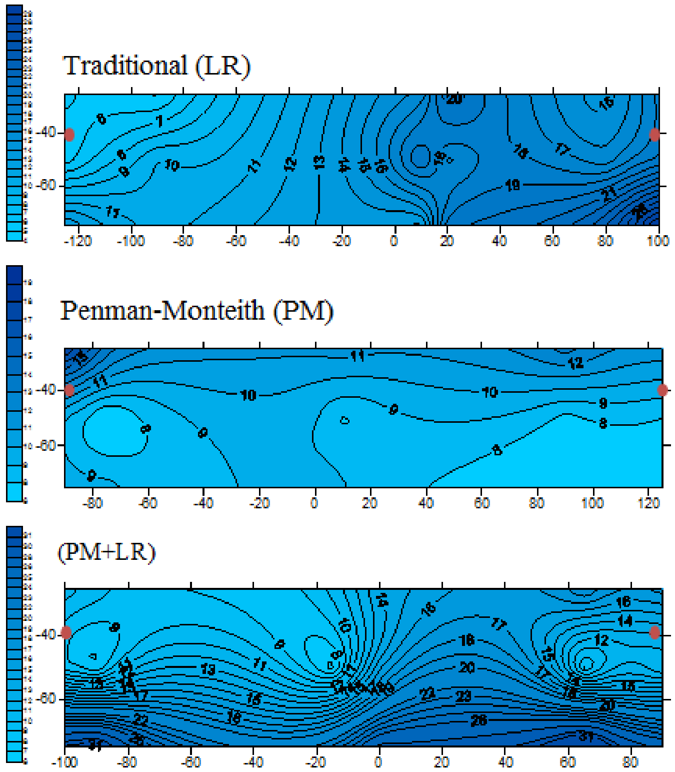
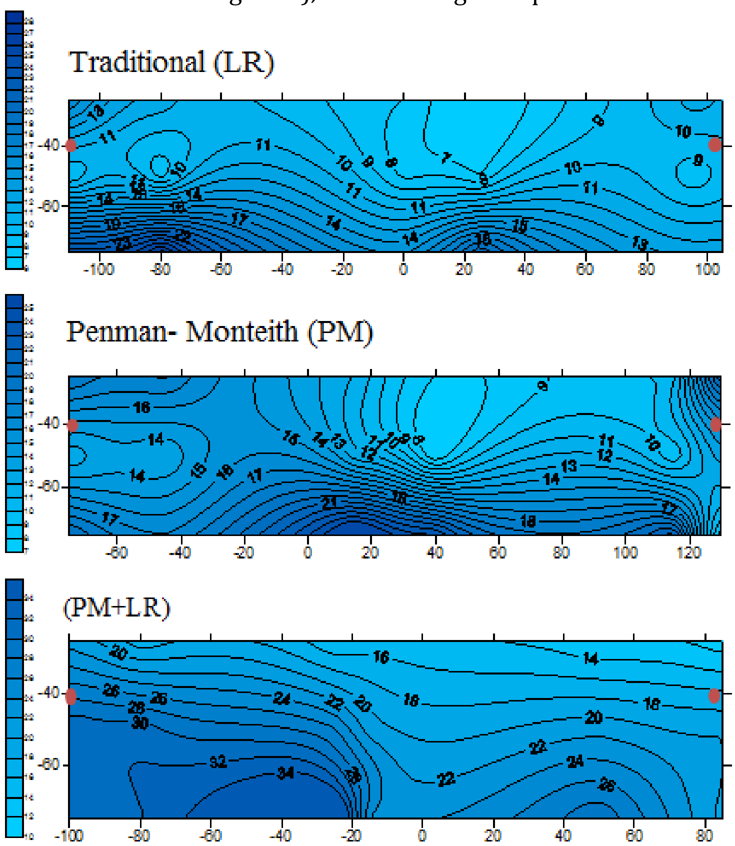


Figure 7: Distribution of percentage of moisture (by volume) after irrigation, October 15th, (208 days after the first irrigation), in three irrigation patterns



To analyze the advancement of moisture and water distribution before and after irrigation, during the midseason growth period, the 18th and 19th of August (151 and 125 days after the first irrigation) – as representative of this period, were selected and sampled.
According to figures 6 and 7, it can be expressed that in I_1 and I_3, the moisture, before and after irrigation, was more below the axis of the emitters. Regarding moisture distribution, due to the upward movement of water, in areas near the surface, water evaporates to the surface, and moisture is higher in deeper areas. But, regarding the distribution of moisture after irrigation, it is expected that 24 hours after irrigation a continuous moisture profile be formed in between the two emitter lines. This expectation was satisfied in all three irrigation patterns. This indicates adequate distance between emitter lines with respect to the irrigation period. Furthermore, according to figures 6 and 7, moisture in irrigation pattern 1 (I_1-Traditional) is less than in irrigation pattern 2 (I_2-PM), and irrigation pattern 3 (I_3-PM+LR) is more than in I_2.

CONCLUSIONS

Results showed that because of keeping moisture level at farming moisture capacity, 24 hours after irrigation, the second irrigation pattern had a more desirable condition relative to the other two irrigation patterns over the entire season of growth and preparing the soil for the next year. Furthermore, this irrigation pattern, avoids using too much water resources due to decreasing the moisture in the soil in the Fall when the plants' water needs become less. In addition, a determination coefficient of 0.57 to 0.90, and RMSE of 0.67 to 4.62 indicate the accuracy of the linear model of HYDRUS-2D in farm settings.

REFERENCES

1. Molaei Kandelous, M. Liaghat A. Abbasi F. (2006) " Simulating the moisture front in subsurface drip irrigation system using HYDRUD-2D model" Masters dissertation. Irrigation and drainage. Irrigation Engineering. Tehran University Pardis Karaj.
2. Bristow, K.I., Cote, P.J., Thotburn, P.J., Cook, F.G (2000). "Soil Wetting and solute transport in trickle irrigation system". In 6th International micro-irrigation conference(micro 2000). 22-27 october 2000. Cape town. South Africa.
3. Li, J., Zhang, J and Rao, M. (2004). "Wetting patterns and nitrogen distributions as affected by fertigation strategies from a surface point source". Journal of Agriculture Water mangement. 67:89-104.
4. Patel Neelam, Rajput T. B. S. (2008)." Dynamics and modeling of soil water under subsurface drip irrigated onion". Journal of Agricultural Water Management. 95:1335 – 1349 .
5. Acar, b., Topak, R., and Mikailsoy, F.(2009). "Effect of applied water and discharge rate on wetted soil volume in loam or clay-loam soil from an irrigated trickle source". Journal of Agriculture Research. 41: 049-054.
6. Lanjabi, M. Tabatabaei, A. Tabatabaei H. Fattah R. Noori M. (2010) "Effects of the usage of geotextile coating on the moisture front in subsurface drip irrigation system" Irrigation and Drainage magazine, 1:101-109
7. Battam, M. A., Sutton, B. G., Boughton, D. G. (2003)." Soil pits as a simple design aid for subsurface drip irrigation systems". Journal Irrigation. Science. 22: 135-141.
8. Thorburn, P. J., Cook, F. J., Bristow, K. L. (2003)." Soil-dependent wetting from trickle emitters: implications for system design and management". Journal of Irrigation Science. 22: 3:121-127.
9. Ben-Gal, A. Lazorovitch, N. Shani, U. (2004). "Subsurface drip irrigation in gravel-filled cavities". Journal Vadose. Zone. 3: 1407-1413.
10. Sayyari, N. Ghahreman, B. Davari K. (2007) "Analysis of soil cations under SDI, Agricultural Sciences and Industries" Mashhad Ferdowsi University, 4:81-93.
11. Khalili, M. Hezarjaripi, A. Akbari, M. Zakerinia, M. (2012) "Determination of moisture profile in subsurface drip irrigation" Masters dissertation, Gorgan University of Agricultural Sciences and Natural Resources.