Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 48 (2012) 9242-9244

ISSN: 2229-712X

Determining suitable probability distribution for estimating wetting front in surface and subsurface Drip Irrigation

Bakhtiar Karimi, Teymour Sohrabi and Farhad Mirzaei

Department of Irrigation and Reclamation, Faculty of Agricultural Engineering and Technology, University of Tehran, Iran.

ARTICLE INFO

Article history:

Received: 15 May 2012;
Received in revised form: 15 June 2012;
Accepted: 29 June 2012;

Keywords

Subsurface drip irrigation,
Wetting bulb,
Frequency distribution,
Relative Residual Square Mean,
Irrigation management.

ABSTRACT

Drip irrigation systems have a preference in selecting a suitable irrigation method in arid and semi-arid regions because of its high potential in uniform applying water in through a field. A proper management of drip irrigation system is, to some extent, dependent upon accurate understanding of wetting patterns distributions in soil under different combinations of soil type and emitter discharge rate. Using statistical distribution to estimate wetting front pattern in drip irrigation systems can improve their performance in different conditions. In this paper, the wetting area and water distribution on light, medium and heavy texture homogeneous soils in subsurface drip irrigation (SDI) and surface irrigation (DI) were evaluated. Experimental tests were carried out in a plexiglass lysimeter container with transparent walls. Emitters were buried at 15, 30 and 45 cm depths and discharge rates of 2.4, 4 and 6 L/h were applied. In this research, data of water front was divided into tree hourly periodic lengths of 2, 4 and 6. Then, with analysis of data in time series according to HYFA software output and goodness fit of Relative Residual Square Mean, suitable frequency distribution function for different conditions was evaluated. Based on relative frequency, the best fitted distribution for DI and SDI was found to be Normal and Pearson type III distribution (Moment method) and Normal distribution (maximum likelihood method).

Introduction

Improving agricultural water use efficiency is crucial in regions with limited water resources. Subsurface drip irrigation (SDI) and surface drip irrigation (DI) can be used to improve irrigation uniformity and water use efficiency in a number of cropping systems by applying a less volume of water to root zones. Application of water below the soil surface, help in saving water since evaporation are greatly reduced and leaching could also be reduced as well. SDI has been practiced since ancient times, including pot irrigation (Bainbridge 2001). This irrigation method would be feasible for irrigation and water conservation in arid regions as well as in areas where water is scarce and power is either unavailable or expensive (Wei Wei et al 2010).

In subsurface drip irrigation systems, emitters are buried below the soil surface so water seeps from the emitters into the soil and spreads out in the root zone due to capillary forces (Wei Wei et al 2010).

Drip irrigations have a preference in selecting a suitable irrigation method in arid and semi-arid regions because of its high potential in uniform applying water in through a field. A proper management of a drip irrigation system is, to some extent, dependent upon accurate understanding of wetting patterns distributions in soil under different combinations of soil type and emitter discharge rate (Li et al 2007).

Hegazi (1998) and Bainbridge (2001) concluded that traditional sub-surface irrigation methods have high water use efficiency, i.e., high crop production for certain applied water. The efficiency may be affected by the water application rate and by design parameters such as the size, depth, and spacing of pipes, etc., which determine the extent of deep percolation water losses and soil saturation problems. Also, evaporation losses are minimized when the wetting front is kept below the soil surface (Siyal et al 2009). Hence, the estimation of the water distribution of the wetted zone for different soils and system designs can be very useful for developing guidelines and criteria for optimizing the performance of traditional sub-surface irrigation systems (e.g. Zur, 1996). Analyses on the effects of application rate on the water distribution pattern showed that for a given volume applied, water moved more laterally the emitter discharge increased while it moves more in the vertical direction as its discharge decreased (Li et al 2004). Karimi et al (2012) were evaluating wetting bulb dimensions in subsurface drip irrigation and surface drip irrigation and results showed that water moved more laterally for higher emitter discharges. Another result this research showed that for higher emitter discharges favored water to move upwards toward the soil surface but the contrary was observed for same applied water. Based on available studies, it's concluded that these researches was done to evaluate wetting pattern (horizontal and vertical) for combinations of emitter discharge rates and soil texture type whereas there're not any studies to estimate water front using statistical distribution. Considering statistical distribution to estimate wetting front pattern in drip irrigation systems can help to improve their performance in different conditions. Then, one of objectives of this study was to evaluate different statistical distributions for wetting patterns in different conditions of discharge rate and soil types. Selecting accurate statistical distribution for geometry of the wetted zone can be very useful to improve the performance of DI and SDI systems.

Tele:
E-mail addresses: bakhtiar.karimi@gmail.com

Materials and methods

These experiments were carried out on a plexiglas lysimeter (3m×1.22m×0.5m) at the central laboratory of the College of Agricultural and Natural Resources of the University of Tehran, Iran. Three air-dried soils samples with physical properties presented in Table 1 were filled exactly into the lysimeter according to soil bulk density. Then in order to prevent preferential flow along the walls, lysimeter walls were treated with glue and sprayed with sand to create a coarse surface (Kandelous and Simunek, 2010).

Emitters were placed at 0, 15, 30 and 45 cm depths and connected to a water reservoir by micro polyethylene tubes (main, sub-main and lateral) with diameters 50, 20 and 16 mm, respectively. The reservoir Volume was 250 L and had a floater indicated water table and discharge rates of 2.4 (Q_1), 4 (Q_2), 6(Q_3) L/h were applied.

A pressure gauge and a valve were placed after pump was used to measure pressure and to maintain steady discharge. All of experiments were performed at fixed pressure (2 bars). Emitter clogging by suspended particle was prevented by the filtration system. An off-on valve placed between of lateral and sub-main to control flow inside each container. In this research, in order to achieve high uniformity, emitters placed on soil surface and water flow convey certain depths by connector. Considering low discharge rate in each experiment, a by-pass assembly installed to regulate inflow and to return additional water to reservoir.

Lysimeter included of three sections that were filled by different soil. The lengths of each container for on light, medium and heavy texture homogeneous soils were 1.2, 0.9 and 0.9 m respectively (The dimensions of them were drawn in fig.1). The container related to clay soil, because high horizontal distribution of water, was larger size than two other containers.

Emitter's technical properties of used emitters in this research were presented in Table 2. Wetting patterns were measured during 6 h. The shapes of the wetting front and wetting bulbs dimensions (horizontal, vertical and radius movement) were drawn visually on the lysimeter transparent walls. In addition, the dimensions of wetting bulbs were measured graded strips located in the lysimeter walls.

Wetting pattern data (radius movement) for DI and SDI (with different emitter depth, 15, 30 and 45 cm) was applied to evaluate fitness of statistical distributions.

According HYFA (Hydrological Frequency Analysis) program results, the best-fitted statistical distribution is considered for DI and SDI with hourly periodic lengths of 2, 4 and 6. In HYFA, relative residual mean square and chi-square test has used and the parameters of the distributions were estimated by the methods of moments and maximum likelihood method.

In this study, normal, two-parameter log-normal, three-parameter log-normal, Gumbel, two parameter gamma, Pearson type III and log Pearson type III distributions were explored. By analyzing relative residual mean square and chi-square test tables (in HYFA output) for different time series (2, 4 and 6 hours during irrigation), the distributions ranked. Finally, the best-fitted probability distribution selected by relative frequency of first classes each statistical distribution.

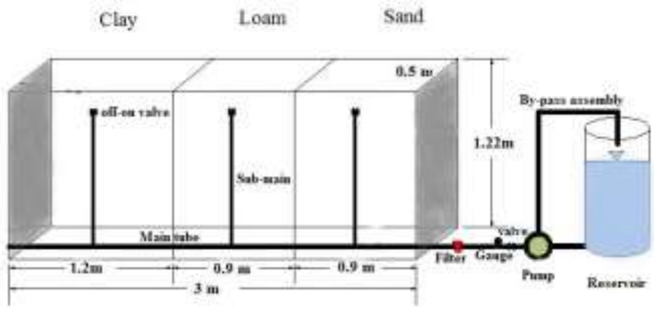

Fig1. Sketch of laboratory set up for the experiments

Results and Discussion

Considering of the best suitable statistical distribution to predict wetting bulb dimensions and water distributions in DI and SDI could aim at the selection of proper design variables (emitter depth), and/or operation variables (irrigation time) in the different soils under different scenarios. Obtaining HYFA results and according to deviation table and values of relative residual mean square, the best statistical distribution that had the least deviation was selected and considered as the best-fitted distribution for the data of water distribution in DI and SDI systems. Analysis of data was done in time series according to HYFA software output (based on Relative Residual Square Mean) and suitable frequency distribution function for different conditions was evaluated.

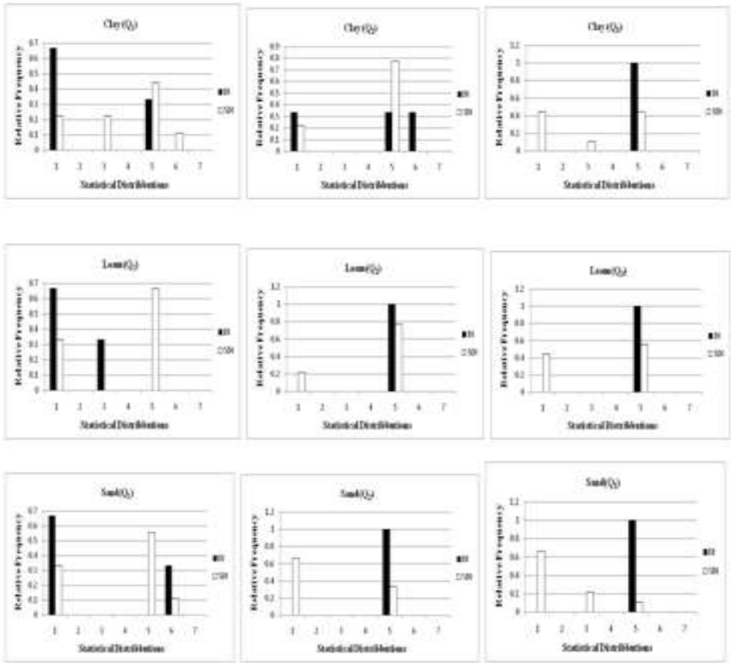

Figure 2. Relative frequency of the first class statistical distribution using maximum moment method. For three types soil texture (heavy (row 1), medium (row 2) and light (row 3)) and three discharge rates (Q1 (column 1), Q2 (column 2), Q3 (column 3)) (1) normal, (2) two-parameter log-normal, (3) three-parameter log-normal, (4) two parameter gamma, (5) Pearson type III, (6) log Pearson type III, (7) Gumbel

Based on relative frequency, the best fitted distribution for both DI and SDI systems was found to be Normal and Pearson type III distribution in Moment method (Fig.2) and Normal distribution in maximum likelihood method (Fig.3). These statistical distributions were evaluate for three types soil texture (heavy (row 1), medium (row 2) and light (row 3)) and three discharge rates (Q_1 (column 1), Q_2 (column 2), Q_3 (column 3)) according with Figures 2 and 3. Using statistical distribution to estimate wetting front pattern in drip irrigation systems can be useful to improve their performance in different conditions. Then, evaluation and selecting accurate statistical distribution (for wetting patterns) to estimate of geometry of the wetted zone in different conditions of discharge rate and soil types can be very useful to improve the performance of DI and SDI systems because accurate estimation of water movement can increase water use efficiency in a number of cropping systems by applying a less volume of water to root zones. Prediction of vertical and horizontal movement can also decrease deep percolation by saving water in root extension zone. Hence, the estimation of the geometry and water distribution of the wetted zone for different soils and discharge rates can be useful for developing guidelines and criteria for optimizing the performance of traditional sub-surface irrigation systems.

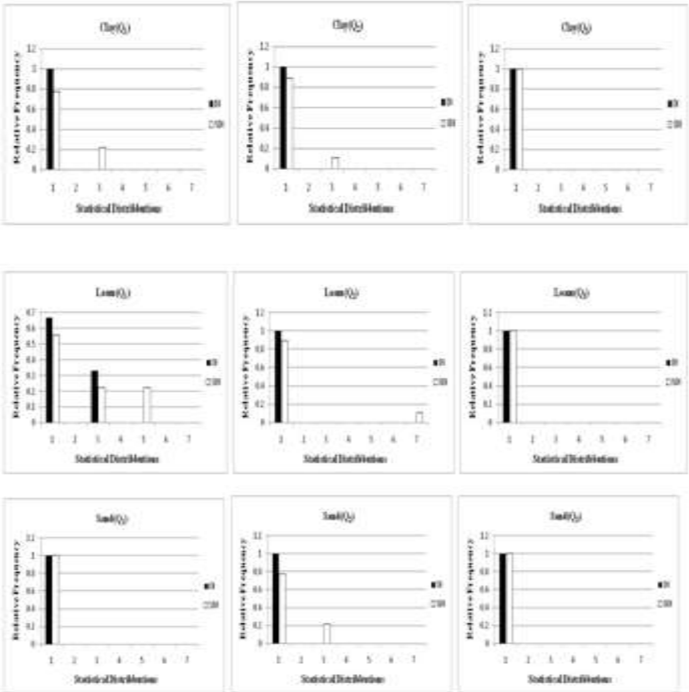

Figure 3. Relative frequency of the first class statistical distribution using maximum maximum likelihood method. For three types soil texture (heavy (row 1), medium (row 2) and light (row 3)) and three discharge rates (Q_1 (column 1), Q_2 (column 2), Q_3 (column 3)) (1) normal, (2) two-parameter log-normal, (3) three-parameter log-normal, (4) two parameter gamma, (5) Pearson type III, (6) log Pearson type III, (7) Gumbel

Reference:

1. Bainbridge DA (2001) Buried clay pot irrigation: a little known but very efficient traditional method of irritation. Agric Water Manage 48(2):79–88.

2. Hegazi, S.M., 1998. Subsurface irrigation method using porous clay pipe. Progress Report, Iranian Agricultural Education and Research Institute, Agricultural Research, Education and Extension Organization, Ministry of Agriculture, Iran (in Persian).

3. Kandelous, M.M., Simunek, J., 2010. Comparison of numerical, analytical and empirical models to estimate wetting pattern for surface and subsurface drip irrigation. Irrig. Sci., doi: 10.1007/s00271-009-0205-9.

4. Kandelous, M.M., Simunek, J., 2010. Numerical simulations of water movement in a subsurface drip irrigation system under field and laboratory conditions using HYDRUS-2D. Journal of Agricultural Water Management 97 (2010) 1070–1076.

5. Karimi, B., Sohrabi, T., Mirzaei, F., Rodriguez-Sinobas, L. 2012. Evaluation of wetting area and water distribution on different soils in subsurface drip irrigation emitters. European Geosciences Union Conference. General Assembly 2012.Vienna, Austria. 22-27 April.

6. Li, Jiusheng., Zhang, J., Rao, M. 2004. Wetting patterns and nitrogen distributions as affected by fertigation strategies from a surface point source. Journal of Agricultural Water Management 67 (2004) 89–104.

7. Li Jiusheng, Ji Hong-yan, Li Bei and LIU Yu-chun. 2007. Wetting Patterns and Nitrate Distributions in Layered-Textural Soils Under Drip Irrigation. Journal of Agricultural Sciences in China. 2007, 6(8): 970-980.

8. Siyal, A.A ., Skaggs, T.H. 2009. Measured and simulated soil wetting patterns under porous clay pipe sub-surface irrigation. Journal of Agricultural Water Management. 96 (2009) 893–904.

9. Wei Wei Yao., Xiao Yi Ma., Juan Li., Martin Parkes. 2010. Simulation of point source wetting pattern of subsurface drip irrigation. Journal of Irrigation Science. DOI 10.1007/s00271-010-0236-2.

10. Zur, B., 1996. Wetted soil volume as a design objective in trickle irrigation. Irrig. Sci. 16, 101–105.

Table 1. Physical properties of soil samples

Samples Name	Sand%	Silt%	Clay%	Soil texture	Bulk density (gr/cm^3)	Particle density (gr/cm^3)	Weighted moisture at field capacity (%)	Weighted moisture at saturation point (%)
Heavy texture	46	18	36	Sandy-clay	1.2	2.65	21.6	37.5
Medium texture	55	22	23	Sandy-clay-loam	1.35	2.65	18.7	34.5
Light texture	76	13	11	Loam-sandy	1.45	2.59	14.1	30.1

Table 2. Technical properties of emitters

Emitter (Netafim model) with discharge rate 6 Lit per hour	Emitter (Netafim model) with discharge rate 4 Lit per hour	Emitter (Swiss drip model) with discharge rate 2.4 Lit per hour	parameter
97	98	98	Distribution Uniformity Coefficient for available emitters (%)
0.012	0.026	0.014	Variety Coefficient for available emitters (%)