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COMPUTER MODEL FOR THE PREDICTION OF WETTING FRONT MOVEMENT IN SOIL UNDER EMITTERS

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ABSTRACT

A two dimensional water flow model for predicating wetting front movement and soil moisture distribution pattern from point and line source of system drip irrigation was developed using Visual Basic of Applications and the finite difference technique (Alternating Direction Implicit).To determine the validity of the mathematically analysis, the computer model was experimentally tested under different conditions. Two types of flow were carried out in clay soils, the first was point source model of discharge rates (2, 4, 8.56 and 16 l/hr), and the second was line source model of discharge rates (4.6, 7.4, 9.23 and 20 l/hr/m) at non linear operating pressure were used in this study. The results of the modeling were good agreement with the experimental testes.

The coefficients of determination of linear regression analysis between predicted and measured soil water content were (0.93, 0.81, 0.92 and 0.82) for (2, 4, 8.56 and 16 l/hr) respectively under point source. And were (0.82, 0.82, 0.84 and 0.77) for (4.6, 7.4, 9.23 and 20 l/hr/m) respectively under line source).So that the computer model could be satisfactorily used to find out soil moisture movement and distribution under different conditions of trickle irrigation.

INTRODUCTION

The fast population growth with a fixed annual quota from the Nile River (55.5 billion cubic metre, where the Nile River is the main source of irrigation water) is considered the major problem blockade the horizontal expansion, the increasing economic growth and the development trickle irrigation can help in this problem by improve the water use efficiency.

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A well-designed trickle irrigation system loses practically no water to runoff, deep percolation, or evaporation. Some important considerations in the design of such a system include the percentage of the root zone which should be watered, the spacing and location of emitters, and the application rates, volumes, and frequencies necessary to attain the desired coverage. The first step in obtaining the data needed to support this phase of the design process is to measure the moisture distribution in various soil profiles for applications of irrigation water of varying rates and amounts (Marcos et al., 1994 ; El-shafei et al., 2008), also dimensions of the wetted pattern, where the depth of wetted pattern should coincide with the depth of the root system while width dimension of wetted pattern should be related to the spacing between emitters and lines (Zur, 1996; Amer et al., 2010).There are many tools to predict soil moisture movement and distribution in soil profile, one of the efficient tools is mathematical modeling of the soil (Marcos et al., 1994; El-nesr et al., 2006). Many dynamic systems, whether they are mechanical, electrical, thermal, hydraulic, economic, etc., may be characterized by differential equations. The equations can be obtained by utilizing physical laws governing a particular system, for example, Darcy's laws for soil moisture movement and distribution in the soil profile. The mathematical description of the dynamic characteristics of a system is called a mathematical model (Ogata, 2002). Computer tools and various analytical can be used for analysis and synthesis purposes for a mathematical model.

Consequently, the main objectives of this study are:

1- Developing a computer model under line-source (plane flow) to simulate soil moisture movement and distribution in the soil profile.

2- Developing a computer model under point source (cylindrical flow) to simulate soil moisture movement and distribution in the soil profile.

3- Studying the relationship between the wetting front movement and different parameters (Application rate, Volume, Time, Type of flow)

4- Comparing between the predicted and observed, measured wetting fronts and a moisture contents to checking the model validity.

MATERIALS AND METHODS

Experiment Location:

The experiments were carried out in Irrigation Laboratory at Tractor and Machinery Testing Station at Alexandria, Agricultural Engineering Researches Institute, Agricultural Researches Center.

Soil physical analysis:

A type of soil was used in this study clay soil (Abeis region). The soil was brought from the top layer of 50 cm depth using a shovel .The soil was placed in bags and transported to irrigation laboratory, a soil type was analyzed to determine particle size distribution and field bulk density (BD) , electrical conductivity (Ec), pH , saturated hydraulic conductivity (Ks), field capacity (FC), permanent wilting point (PWP), saturation water content (θs). These tests were carried out according to the procedure described in the methods for soil analysis **(Black et al., 1982)**, the results of the soil characteristics are presented in Table (1).

Table 1: Some soil physical and chemical characteristics of the soil type

Depth (cm)	Particle size distribution %			Texture	FC % vol.	PWP % vol.	BD g/cm^3	Ks m/s	θs % vol.	pH	EC ds/m
	Sand	Silt	Clay								
0-50	12.15	34.55	53.3	clay	44.4	24.1	0.95	0.0091	0.54	7.9	1.36

Experimental apparatus:

Experimental studies were conducted on a glass rectangular soil box (50 length x 50 width x 60 depth cm), used glass to observe the wetting front and simulate a soil section in the field (dimensions of wetted pattern). The emitter line (16mm diameter PE) was laid on the surface and consisted of a single emitter in the corner of the soil box for simulate point source (cylindrical flow) and consisted of the number of emitters were laid beside the front side of the soil box for simulate line source (plane flow). The emitter line was closed tightly and the other end connected to pressure gauge, control valve (to find the discharge rate corresponding to the emitter pressure), an electric pump (Calpeda, 0.75 Kw) to supply a several discharge rates for all experiments, and water tank (416Litters).

Experimental procedure:

The soil was sieved through 2mm mesh number size sieve and air-dried to certain water content dry weight basis. The soil was placed into the soil box in 10 cm layers and compacted for arrive to the certain bulk density (0.95 g / cm^3) up to the soil box was filled.

This study was conducted on two different types of the flow, the first type (point source) were conducted with the emitters Netafim (PCJ, Pressure compensating) at flow rates (2, 4, 8.56, 16 l/hr) where Pressure compensating for the working pressure range (0.5 – 4 bar). And during the experiments the operating pressure values were (1, 1.3, 1.5 and 2 bar) respectively. The second type (line source) were conducted with numbers of emitters per meter (Netafim, Button, Non pressure compensating) were the operating pressure values (0.5, 0.7, 1 and 1.5 bar) and the number of emitters per meter were (4, 5, 5, 9) to supply the different discharge rates (4.6, 7.4, 9.23, 20 l/hr/m) respectively.

During each experiment, the wetting front contour was drawn each 60 minutes on the transparent paper sheet for all direction. And at the end of the experiment (after 2 and 4 hr), the soil samples were taken from different depths to determine the moisture distribution.

Procedure of first modeling (Point Source) :

Consider a number of nozzles spaced far enough apart to prevent overl(single emitter). The flow called "cylindrical flow" and involving the cylindrical coordinate's r and z.The differential equation that governs the cylindrical flow according to **Brandt et al. (1971)** as:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial r}\left(D(\theta)\frac{\partial \theta}{\partial r}\right) + \frac{1}{r}\frac{\partial \theta}{\partial r} D(\theta) + \frac{\partial}{\partial z}\left(D(\theta)\frac{\partial \theta}{\partial z}\right) - \frac{\partial}{\partial z} K(\theta) \ldots (1)$$

Where:

θ: the soil water content based on volumetric (m^3 / m^3)

t: irrigation time (s)

D (θ): the soil water diffusivity (m^2 / s)

K (θ): the hydraulic conductivity of the soil (m / s) r: the radial coordinate.

Z: the vertical coordinate which is considered to be positive downward.

The initial and boundary conditions

The initial condition at starting time according to **Brandt et al. (1971)** assumed that the water content is a constant value at any point of a grid as

$\theta_{i,j} = \theta_{ini}$ i=0,1,2,........N,N+1 ,and j=0,1,2,........M,M+1

The boundary conditions are:

1- At the soil surface according to **Brandt et al. (1971)** and by used the finite difference method obtains:

$$\sum_{i=1}^{is-1} 2\pi\, r_i\, \Delta r \left(K_{i,0}^{n+1} + E_{i,0}^{n+1} - \frac{-3\,S_{i,0}^{n+1} + 4\,S_{i,1}^{n+1} - S_{i,2}^{n+1}}{2\,\Delta z} \right) = Q = F_i \quad \text{..........(2)}$$

From previous equation we can define the margin of a saturated zone (i_{sat}) and divide the soil surface of two parts, **the first part** according to **Brandt et al. (1971) as:**

$$\theta_{i,0} = \theta_{i,1} - \frac{\Delta z}{D(\theta_{i,0})} \left(K(\theta_{i,0}) + E(\theta_{i,0}) - Q / \Pi (\Delta r\, i)^2 \right)$$

$$\text{for } 0 \le i \le i_{sat} \text{ and } j = 0 \qquad \text{........ (3)}$$

And **the second part** according to **Brandt et al. (1971)** as:

$$\theta_{i,0} = \theta_{i,1} - \frac{\Delta z}{D(\theta_{i,0})} \left(K(\theta_{i,0}) + E(\theta_{i,0}) \right) \qquad \text{........ (4)}$$

2- Along the vertical side under emitter source (at i=0 and j=1, 2, 3 .....M), the flow equation is according to **Smith (1985)** as:

$$\frac{\partial \theta}{\partial t} = 2\,D(\theta) \frac{\partial^2 \theta}{\partial r^2} + D(\theta) \frac{\partial^2 \theta}{\partial z^2} - \frac{\partial k(\theta)}{\partial z} \qquad \text{......... (5)}$$

The last equation can be transformed to finite difference according to **Selim and Kirkham (1973)** as:

$$a_{i,j}^{n}\, \theta_{i,j-1}^{n+1} + b_{i,j}^{n}\, \theta_{i,j}^{n+1} + c_{i,j}^{n}\, \theta_{i,j+1}^{n+1} = e_{i,j}^{n} \qquad \text{....... (6)}$$

Where:

$$a^{n}_{i,j} = -\mu D(\theta^{n}_{i,j-1/2})$$

$$b^{n}_{i,j} = 1+\mu D(\theta^{n}_{i,j+1/2}) + \mu D(\theta^{n}_{i,j-1/2})$$

$$c^{n}_{i,j} = -\mu D(\theta^{n}_{i,j+1/2})$$

$$e^{n}_{i,j} = [1-4\mu D(\theta^{n}_{i+1/2,j})]\theta^{n}_{i,j} + 4\mu D(\theta^{n}_{i+1/2,j})\ \theta^{n}_{i+1,j} - \beta[K(\theta^{n}_{i,j+1}) - K(\theta^{n}_{i,j-1})]$$

The main solution of the first modeling

The alternating direction implicit (ADI) method for parabolic partial differential equations is described by **Brandt et al. (1971)** and **Chapra and Canale (2002)**. The ADI method utilizes two simultaneous systems of difference equations. The two systems together represent the partial differential equation of flow, equation (1) .when a given problem is solved on the computer; the two systems are utilized alternately until the desired simulation time is reached

The first stage:

During the first stage the solution is advanced from time (t^{n}) to an intermediate time (t^{n+1}) by the finite difference. Where r-direction is explicit, while z-direction is implicit, thus and transformed the equation (1) to finite difference format according to **Selim and Kirkham (1973)** as:

$$a^{n}_{i,j}\,\theta^{n+1}_{i,j-1} + b^{n}_{i,j}\,\theta^{n+1}_{i,j} + c^{n}_{i,j}\,\theta^{n+1}_{i,j+1} = e^{n}_{i,j} \qquad \ldots (7)$$

Where:

$a^{n}_{i,j}$, $b^{n}_{i,j}$ and $c^{n}_{i,j}$ as the equation (6)

$$e^{n}_{i,j} = [\mu D(\theta^{n}_{i-1/2,j}) - \frac{\mu}{2i} D(\theta^{n}_{i,j})]\,\theta^{n}_{i-1,j} + [1-\mu D(\theta^{n}_{i+1/2,j}) - \mu D(\theta^{n}_{i-1/2,j})]\,\theta^{n}_{i,j} + [\mu D(\theta^{n}_{i+1/2,j}) + \frac{\mu}{2i} D(\theta^{n}_{i,j})]\,\theta^{n}_{i+1,j} - \beta[K(\theta^{n}_{i,j+1}) - K(\theta^{n}_{i,j-1})]$$

The second stage:

During the second stage the solution is advanced from time (t^{n+1}) to an intermediate time (t^{n+2}) by the finite difference. Where z-direction is explicit, while r-direction is implicit, thus and transformed the equation (1) to finite difference format according to **Selim and Kirkham (1973)** as:

$$a_{i,j}^{n+1}\,\theta_{i-1,j}^{n+2} + b_{i,j}^{n+1}\,\theta_{i,j}^{n+2} + c_{i,j}^{n+1}\,\theta_{i+1,j}^{n+2} = e_{i,j}^{n+1} \quad \text{..........(8)}$$

Where:

$$a_{i,j}^{n+1} = \frac{\mu}{2i} D(\theta_{i,j}^{n+1}) - \mu D(\theta_{i-1/2,j}^{n+1})$$

$$b_{i,j}^{n+1} = 1 + \mu D(\theta_{i+1/2,j}^{n+1}) + \mu D(\theta_{i-1/2,j}^{n+1})$$

$$c_{i,j}^{n+1} = -\mu D(\theta_{i+1/2,j}^{n+1}) - \frac{\mu}{2i} D(\theta_{i,j}^{n+1})$$

$$e_{i,j}^{n+1} = \mu D(\theta_{i,j-1/2}^{n+1})\ \theta_{i,j-1}^{n+1} + [1 - \mu D(\theta_{i,j+1/2}^{n+1}) - \mu D(\theta_{i,j-1/2}^{n+1})]\,\theta_{i,j}^{n+1} + [\mu D(\theta_{i,j+1/2}^{n+1})]\,\theta_{i,j+1}^{n+1} - \beta\,[K(\theta_{i,j+1}^{n+1}) - K(\theta_{i,j-1}^{n+1})]$$

Procedure of second modeling (Line source)

Line Source (Plane flow) model :

Consider a set of trickle sources that are spaced at equal intervals along an infinite straight line. If the sources are spaced very close to each other ($Y \rightarrow 0$), the flow becomes independent of the (y) coordinate. The flow called "plane flow" and involving the Cartesian coordinates x and z

The differential equation that governs the plane flow according to **Brandt et al. (1971)** as:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left(D(\theta)\frac{\partial \theta}{\partial x}\right) + \frac{\partial}{\partial z}\left(D(\theta)\frac{\partial \theta}{\partial z}\right) - \frac{\partial}{\partial z}K(\theta) \quad \text{.........(9)}$$

The initial and boundary conditions

The initial condition at starting time according to **Brandt et al. (1971)** assumed that the water content is a constant value at any point of a grid as

$\theta_{i,j} = \theta_{ini}$ i=0,1,2,........N,N+1 ,and j=0,1,2,........M,M+1

The boundary conditions are:

1- At the soil surface according to **Brandt et al. (1971)** and by used the finite difference method obtains:

$$\sum_{i=1}^{is-1} 2\Delta x \left(K_{i,0}^{n+1} + E_{i,0}^{n+1} - \frac{-3\,S_{i,0}^{n+1} + 4\,S_{i,1}^{n+1} - S_{i,2}^{n+1}}{2\,\Delta z} \right) = Q = F_i \quad \text{......... (10)}$$

From previous equation we can define the margin of a saturated zone (i_{sat}) and divide the soil surface of two parts, **the first part** according to **Brandt et al. (1971) as:**

$$\theta_{i,0} = \theta_{i,1} - \frac{\Delta z}{D(\theta_{i,0})} \left(K(\theta_{i,0}) + E(\theta_{i,0}) - Q / 2\,\Delta x\, i\right)$$

$$\text{for } 0 \le i \le i_{sat} \text{ and } j = 0 \quad \text{... (11)}$$

And **the second part** according to **Brandt et al. (1971)** as:

$$\theta_{i,0} = \theta_{i,1} - \frac{\Delta z}{D(\theta_{i,0})} \left(K(\theta_{i,0}) + E(\theta_{i,0})\right) \quad \text{... (12)}$$

<u>The main solution of the second modeling</u>

As the main solution of the first modeling except used the equation (9)

<u>The first stage:</u>

As the first stage of the first modeling except x-direction is explicit, and transformed the equation (9) to finite difference format according to **Selim and Kirkham (1973)** as:

$$a_{i,j}^{n}\,\theta_{i,j-1}^{n+1} + b_{i,j}^{n}\,\theta_{i,j}^{n+1} + c_{i,j}^{n}\,\theta_{i,j+1}^{n+1} = e_{i,j}^{n} \quad \text{... (13)}$$

Where:

$a_{i,j}^{n}$, $b_{i,j}^{n}$ and $c_{i,j}^{n}$ as the equation (6)

$$e_{i,j}^{n} = [\mu D(\theta_{i-1/2,j}^{n})\,\theta_{i-1,j}^{n} + [1 - \mu D(\theta_{i+1/2,j}^{n}) - \mu D(\theta_{i-1/2,j}^{n})]\,\theta_{i,j}^{n}$$

$$+ [\mu D(\theta_{i+1/2,j}^{n})\,\theta_{i+1,j}^{n} - \beta\,[K(\theta_{i,j+1}^{n}) - K(\theta_{i,j-1}^{n})]$$

The last equation used also along the vertical side of section except but ($\theta_{i+1,j} = \theta_{i-1,j}$) and the new equation name (equation 13").

The second stage:

As the second stage of the first modeling except x-direction is implicit, and transformed the equation (9) to finite difference format according to **Selim and Kirkham (1973)** as:

$$a_{i,j}^{n+1}\,\theta_{i-1,j}^{n+2} + b_{i,j}^{n+1}\,\theta_{i,j}^{n+2} + c_{i,j}^{n+1}\,\theta_{i+1,j}^{n+2} = e_{i,j}^{n+1} \qquad \ldots (14)$$

Where:

$$a_{i,j}^{n+1} = -\mu D(\theta_{i-1/2,j}^{n+1})$$

$$b_{i,j}^{n+1} = 1 + \mu D(\theta_{i+1/2,j}^{n+1}) + \mu D(\theta_{i-1/2,j}^{n+1})$$

$$c_{i,j}^{n+1} = -\mu D(\theta_{i+1/2,j}^{n+1})$$

$$e_{i,j}^{n+1} = \mu D(\theta_{i,j-1/2}^{n+1})\,\theta_{i,j-1}^{n+1} + [1 - \mu D(\theta_{i,j+1/2}^{n+1}) - \mu D(\theta_{i,j-1/2}^{n+1})]\,\theta_{i,j}^{n+1} + [\mu D(\theta_{i,j+1/2}^{n+1})]\,\theta_{i,j+1}^{n+1} - \beta\,[K(\theta_{i,j+1}^{n+1}) - K(\theta_{i,j-1}^{n+1})]$$

Steps of modeling solution:

1- Determine (I_{sat}) for stage 1:

Assume (i=1) and calculate the accumulated flow (Fi) from equations (2 or 10) for point and line source respectively, if the accumulated flow is less than the emitter flow rate (Q), put (i=i+1) and calculate the accumulated flow until ($Fi \geq Q$) then the current column I is I_{sat} ($I_{sat} = I$) for stage 1.

2- Calculate the first row of the grid:

Calculate $\theta_{I,0}^{n+1}$ at $1 \leq i \leq Is$, from equations (3 or 11) for point and line source respectively and Calculate $\theta_{I,0}^{n+1}$ at $I_{S}+1 \leq i \leq r_{max}$, from equations (4 or 12) for point and line source respectively.

3-Calculate the first column of the grid at i= 0 :

Calculate coefficients $a_{i,j}^{n}$, $b_{i,j}^{n}$, $c_{i,j}^{n}$, and $e_{i,j}^{n}$ from equations (6 or 13") for point and line source respectively, now have tri-diagonal system solve with Thomas algorithm to find the first column of grid ($\theta^{n+1}_{i,j}$)

4- Calculate the several columns for stage 1:

Form I = 1 to I= r_{max}, Calculate coefficients $a_{i,j}^{n}$, $b_{i,j}^{n}$, $c_{i,j}^{n}$, and $e_{i,j}^{n}$ from equations (7 or 13) for point and line source respectively, now have tri-diagonal system solve with Thomas algorithm, to find the several columns of grid ($\theta^{n+1}_{i,j}$) for stage 1.

5- Now all points of the grid are know for stage 1:

And put Time now = Time now + step time

6- Determine (I_{sat}) for stage 2:

Recalculate as step (1)

7- Calculate the first row of the grid:

Recalculate as step (2)

8-Calculate the first column of the grid at i= 0 :

Recalculate as step (3)

9- Calculate the several rows for stage 2:

Form J = 1 to J= z_{max} , Calculate coefficients $a_{i,j}{}^{n}$, $b_{i,j}{}^{n}$, $c_{i,j}{}^{n}$, and $e_{i,j}{}^{n}$ from equations (8 or 14) for point and line source respectively, now have tri-diagonal system solve with Thomas algorithm, to find the several rows of grid ($\theta^{n+1}_{i,j}$) for stage 2.

10- Now all points of the grid are know for stage 2:

And put time now = time now + step time.

If time now < irrigation time then go to step (1), except end simulation.

RESULTS AND DISCUSSION

The theoretical results are obtained from the model under discharge rates (2, 4, 8.56 and 16 l/hr) with point source model and under discharge rates (4.6, 7.4, 9.23 and 20 l/ hr/m) with line source model to simulate wetting front movement and water content distribution, and are compared with results obtained from a laboratory experiment where the conditions are similar to those assumed in the theoretical line source model and point source model.

1-Wetting front movement

The experimental results and the theoretical results obtained from the computer program for the wetting front movement under the same conditions are illustrated in Figures (1) through (8).Where in each test, a laboratory experiment was conducted and its results of wetting front movement were compared with the theoretical results obtained from running the computer program under the same initial and boundary conditions of the laboratory experiment.

Contour lines of wetting front for the defined at different times 60,120,180 and 240 min were plotted. A comparison are illustrated

a good agreement between the predictions of the theoretical model and experimental results was obtained.

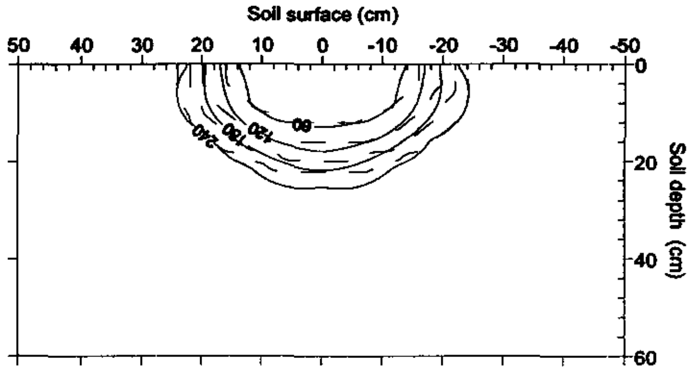

Fig 1: Comparison between observed and predicted wetting front as a function of the time (min) under (point source, 2 l/hr)

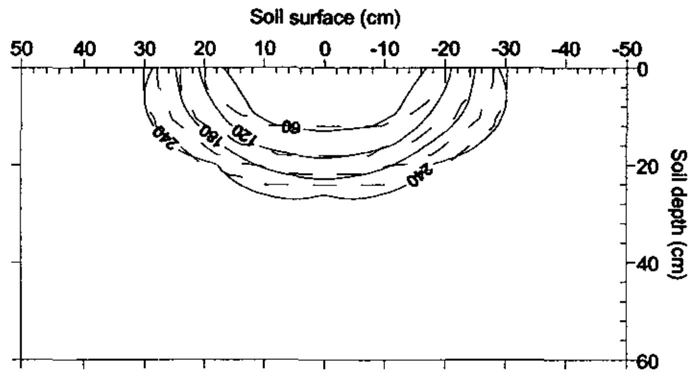

Fig 2: Comparison between observed and predicted wetting front as a function of the time (min) under (point source, 4 l/hr)

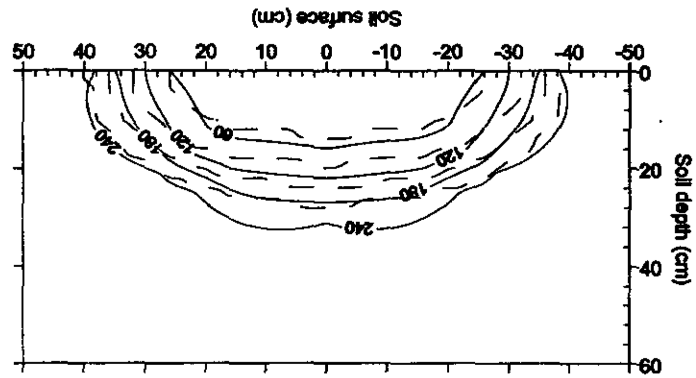

Fig 3: Comparison between observed and predicted wetting front as a function of the time (min) under (point source, 8.56 l/hr)

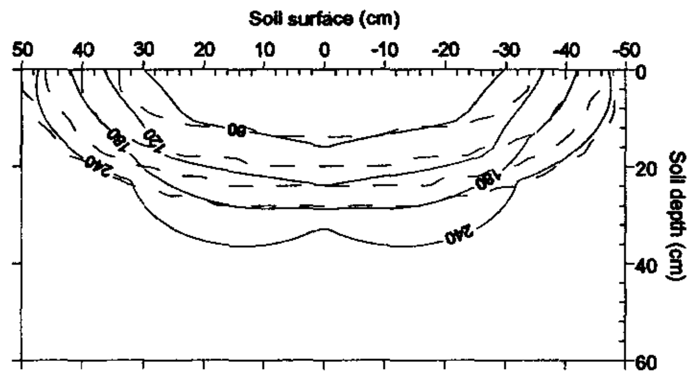

Fig 4: Comparison between observed and predicted wetting front as a function of the time (min) under (point source, 16 l/hr)

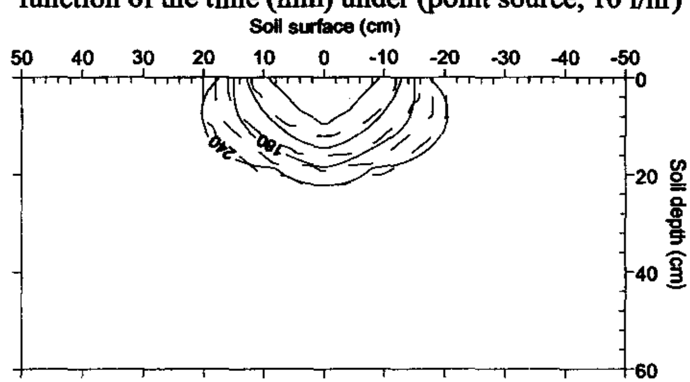

Fig 5: Comparison between observed and predicted wetting front as a function of the time (min) under (line source, 4.6 l/h/m)

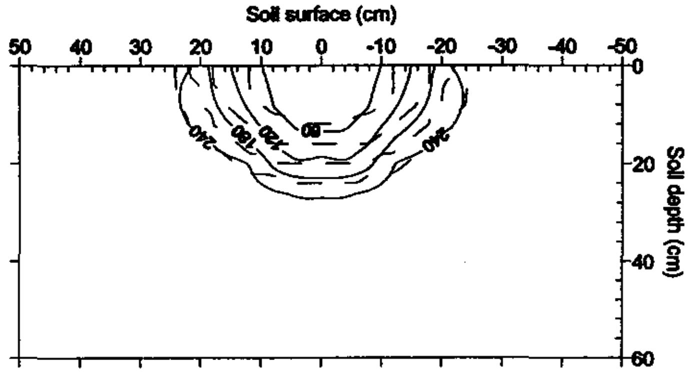

Fig 6: Comparison between observed and predicted wetting front as a function of the time (min) under (line source, 7.4 l/h/m)

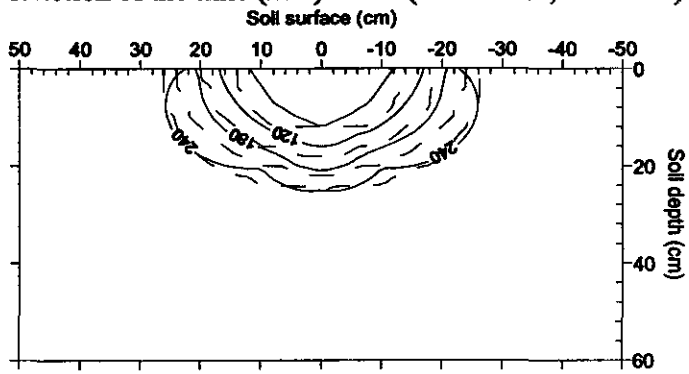

Fig 7: Comparison between observed and predicted wetting front as a function of the time (min) under (line source, 9.23 l/h/m)

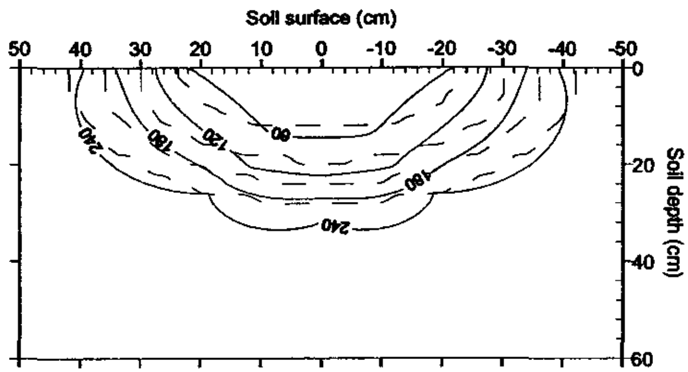

Fig 8: Comparison between observed and predicted wetting front as a function of the time (min) under (line source, 20 l/h/m)

2-Linear regression analysis

The coefficients of determination of linear regression analysis between predicted and measured soil water content were (0.93, 0.81, 0.92 and 0.82) for (2, 4, 8.56 and 16 l/hr) respectively and simulation times (2 and 4 hr) under point source are presented in figures (9) through (12). And were (0.82, 0.82, 0.84 and 0.77) for (4.6, 7.4, 9.23 and 20 l/hr/m) respectively and simulation times (2 and 4 hr) under line source are presented in figures (13) through (16). The coefficients of determination for this comparison indicating that the model prediction can be depended upon the simulation to evaluate the soil water content under several conditions.

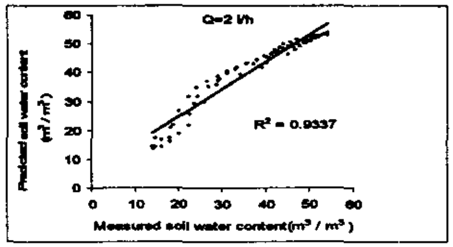

Fig 9: Linear regression analysis between predicted and measured water content for the 2 l/hr discharge rate (point source)

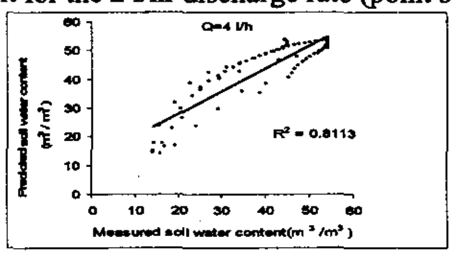

Fig 10: Linear regression analysis between predicted and measured water content for the 4 l/hr discharge rate (point source)

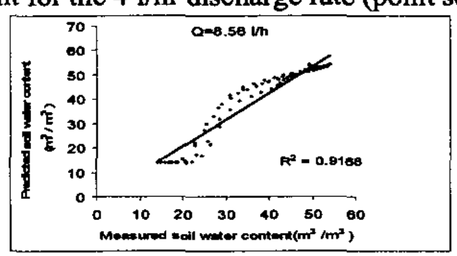

Fig 11: Linear regression analysis between predicted and measured water content for the 8.56 l/hr discharge rate (point source)

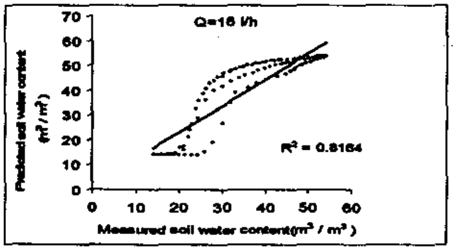

Fig 12: Linear regression analysis between predicted and measured water content for the 16 l/hr discharge rate (point source)

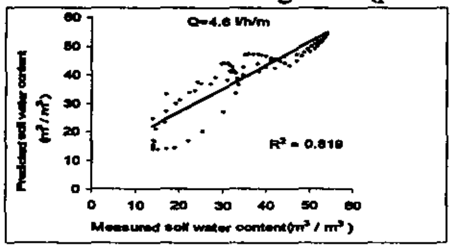

Fig 13: Linear regression analysis between predicted and measured water content for the 4.6 l/h/m discharge rate (line source)

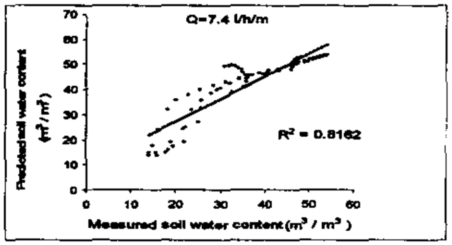

Fig 14: Linear regression analysis between predicted and measured water content for the 7.4 l/hr/m discharge rate (line source)

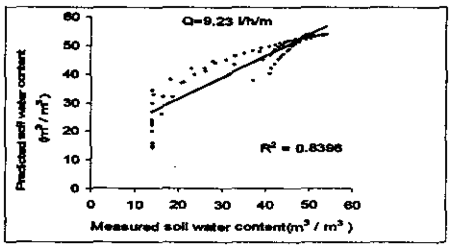

Fig 15: Linear regression analysis between predicted and measured water content for the 9.23 l/hr/m discharge rate (line source)

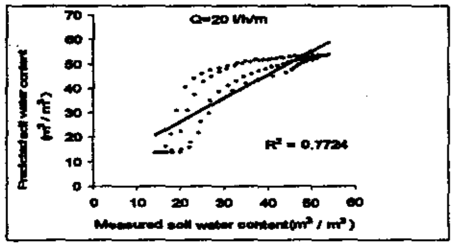

Fig 16: Linear regression analysis between predicted and measured water content for the 20 l/hr/m discharge rate (line source)

CONCLUSIONS AND RECOMMENDATIONS

- It can be concluded from the above results that:

  The finite differences technique followed in modeling and the alternating direction implicit (ADI) method for solving unsteady two-dimensional water flow equation under surface trickle irrigation have been proved to be accurate and dependable.

It can be recommended from this study that:

1-This model can be used to predict the wetted front movement and the soil moisture distribution under surface trickle irrigation.

2-This model can be extended to predict the wetted front movement and the soil moisture distribution under subsurface trickle irrigation.

3- The model can be tested for different soil types.

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<u>**الملخص العربي**</u>

نموذج حاسب آلي للتنبؤ بحركه جبهة الابتلال فى التربه تحت النقاطات

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زيادة أستخدام نظم الري بالتنقيط تبدو واضحه حول العالم كطريق لتحسين كفاءة أستخدام المياه . وفي مصر حيث موارد المياه قليله ومحدوده ، لذلك تعتبر نظم الري بالتنقيط طريقه هامه للمحافظه على المياه وتقليل فواقدها ورفع كفاءة أستخدامها. كما تعتبر أبعاد منطقة الابتلال من أهم العوامل التى تساعد فى التصميم الجيد للنظام كما يعتبر معرفه التوزيع الرطوبي لقطاع التربه هام في عمليه الاداره المثلى للنظام.

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وهناك العديد من الادوات المستخدمه في التنبؤ بالتوزيع الرطوبي وتقدم جبهه الابتلال في قطاع التربه ، أحدي هذه الادوات الفعاله هي النمذجه الرياضيه وفي هذه الدراسه تم حل المعادله التى توصف حركه وتوزيع المياه داخل قطاع التربه فى القطاعات المشبعه وغير المشبعه بأستخدام طريقه الفروق الدقيقه (Finite difference method) مع الحل التبادلي الضمني (A. D. I.)

ألاهداف الاساسيه لهذه الدراسه:

١- تطوير نموذج حاسب ألي ليحاكي حركه وتوزيع المياه فى قطاع التربه من مصدر للمياه فى شكل خطي (Line-source) .

٢- تطوير نموذج حاسب ألي ليحاكي حركه وتوزيع المياه فى قطاع التربه من مصدر للمياه فى شكل أسطوانى (Point-source) .

٣- دراسه العلاقه بين تقدم حركه الابتلال مع بعض المتغيرات (معدل التصرف – الحجم المضاف – زمن الري – شكل حركه المياه من مصدر التنقيط)

٤- مقارنه بين نتائج نموذج المحاكاه وبين النتائج المتحصل عليها من التجارب بغرض تقيم النموذج .

نتائج الدراسه:

١- نسبه الاختلاف للتنبأ بقطر الابتلال تتراوح من (٠% إلى ١٧،٦٥ %) ولعمق الابتلال بين (- ١٧،٢ % إلى -٢،٧ %) تحت معدلات تصرف (٢- ٤ - ٨،٥٦ – ١٦ ل/ س) من مصدر للمياه فى شكل أسطوانى.

٢- نسبه الاختلاف للتنبأ بقطر الابتلال تتراوح من (٥،١١ % إلى ٢٦،٣٢ %) ولعمق الابتلال بين (- ٢،٧ % إلى ٢٠ %) تحت معدلات تصرف (٤،٦ - ٧،٤ – ٩،٢٣ – ٢٠ ل/ س/ م) من مصدر للمياه فى شكل خطي.

٣- جبهه الابتلال الافقيه والرأسيه تتقدم مع الزمن عند تصرف محدد وتتقدم عند زيادة معدل التصرف عند نفس الزمن .

٤- خطوط الكنتور الممثله لقيم المحتوي الرطوبي المقاس تقاربت مع القيم المتنبأ بها عند معدلات تصرف وأنماط سريان وأزمنه محاكاه مختلفه والسبب الرئيسى فى ذلك هو أستخدام طريقه الحل التبادلى الضمني مع شروط حديه

مناسبه(كما في تقدير قيم الصف الاول لقطاع السريان) .

٥- قيم معامل التقدير بين المحتوي الرطوبي المتنبأ به والمقاس كانت (٩٣ % - ٨١ % - ٩٢ % - ٨٢ %) تحت معدلات تصرف (٢- ٤ - ٨،٥٦ – ١٦ ل/ س) من مصدر للمياه فى شكل أسطوانى بينما كانت (٨٢ % - ٨٢ % - ٨٤ % - ٧٧ %) تحت معدلات تصرف (٤،٦ - ٧،٤ – ٩،٢٣ – ٢٠ ل/ س/ م) من مصدر للمياه فى شكل خطي .