Al-Khwarizmi Engineering Journal, Vol. 15, No. 4, December, (2018)
P.P. 103- 114

Al-Khwarizmi Engineering Journal

Numerical Simulation of Unsaturated Soil Water Flow from a Trickle Point System, Considering Evaporation and Root Water Uptake

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(Received 14 March 2018; accepted 29 May 2018)
https://doi.org/10.22153/kej.2018.05.005

Abstract

This research was carried out to study the effect of plants on the wetted area for two soil types in Iraq and predict an equation to determine the wetted radius and depth for two different soil types cultivated with different types of plants, the wetting patterns for the soils were predicted at every thirty minute for a total irrigation time equal to 3 hr. Five defferent discharges of emitter and five initial volumetric soil moisture contents were used ranged between field capacity and wilting point were utilized to simulate the wetting patterns. The simulation of the water flow from a single point emitter was completed by utilized HYDRUS-2D/3D software, version 2.05. Two methods were used in developing equations to predict the domains of the wetting pattern. The principal strategy manages each soil independently and includes plotting, fitting, and communicating relevant connections for wetted zone and profundity, maximum error did not exceed 31.2%, modeling efficiency did not less 0.95, and root mean square error did not surpass 1.43 cm. The second strategy additionally treated each soil independently yet used electronic programming that uses different relapse methods for wetted territory and profundity, the maximum error did not exceed 15.64 %, modeling efficiency did not less 0.98, and root mean square error did not surpass 1.18 cm. a field test was directed to quantify the wetted radius to check the outcome acquired by the software HYDRUS-2D, contrast the estimation and the reproduced by the software. The after effects of the conditions to express the wetted radius and depth regarding the time of water system, producer release, and initial soil moisture content were general and can be utilized with great precision.

Keywords: *Numerical simulation, Richard's equation, root water uptake, soil moisture content.*

1. Introduction

The principles of soil water flow due to irrigation have been investigated by many researchers. According to [1], for standard irrigation practice, water flow within soil may be classified in three phases: infiltration this process starts with the application of water and ends with cessation of irrigation and depletion of surface storage, redistribution water movement in the downward and horizontal directions does not cease immediately after infiltration and may endure for quite a while as soil water redistributes inside the profile. The soil volume wetted to close immersion amid penetration does not hold its full water content since a portion of its water moves into the soil grid affected by gravity and suction inclinations, withdrawal this is mainly absorption of water by plant roots to supply transpiration requirements.

The simulation of water flow in homogeneous unsaturated soil is typically accomplished by solving the Richard's equation [2], [3] simplified a method for predicting the wetted radius from a point source emitter. [4] modified the Bresler's model offer trickle system designers a tool for obtaining a reasonable estimate of the wetted [5] predicted a numerical model to analyzed soil water content distributions under trickle irrigation. [6] estimated a method for soil-water movement under a trickle surface by analyzed the idea of two experimental connections: the principal portrays vertical water development amid infiltration ration, while the second depicts

vertical water development amid the redistribution of the water in the soil profile. [7] compared HYDRUS-2D simulations of drip irrigation with experimental data. They determined the distribution of water content in the soil by gravimetric testing. By utilizing the software HYDRUS-2D forecasts the distribution of water content is observed to be in great concurrence with the information. The outcomes bolster the utilization of HYDRUS-2D as an instrument for examining and planning dribble water system management practices. [8] presented a method for estimating the depth of the wetted soil volume under a surface trickle line source. [9] presented technique for evaluating the surface radius and depth of the wetted soil volume under a surface point source, Verification of the proposed strategy occurred against figured outcomes from a barrel shaped stream show that considers water take-up by roots and vanishing from the soil surface. The presumptions consolidated were those of homogeneous soils, uniform beginning dampness content and a non-hysteretic moisture content-pressure head connection. [10] studied the impacts of discharge rate, a span of the water and separations of between inter-emitter on the wetting front propel designs and on deep percolation under surface trickle irrigation system. They utilized a round and hollow stream display consolidating vanishing and water extraction by roots, keeping in mind the end goal to upgrade the utilization of water system water. [11] investigated the effect of irrigation amount, frequency, and drip line depth on the wetting soil volume, deep percolation, and soil salinity levels under subsurface trickle irrigation (SDI) using HYDRUS-2D/3D. The reproductions showed that lower water system recurrence expanded the wetted soil volume without critical increment in water permeates underneath the plant roots. Profound permeation diminished as the measure of water system water and producer profundity diminished. With a similar measure of water system water, the volume of filtered soil was bigger at bring down water system recurrence. The saltiness of water system water under SID with shallow producer profundity did not demonstrate any huge impact on expanding the soil saltiness above tomato crop salt resistance. [12] investigated soil water dynamics under surface drip irrigation from equidistant line sources using a simulation model. In this model two-dimensional appropriations of roots and in addition a more balanced path for the fleeting conveyance of the day by day potential evapotranspiration are additionally consolidated, the outcomes likewise demonstrated that the water system effectiveness and the real dissipation diminish when the water system measurements or the separation between the line sources increments. By differentiate, the deep percolation increases when the irrigation dose or the distance between the line sources increases. [13] investigated the effects of soil hydraulic properties, initial soil moisture content, and irrigation regime on soil water and salinity distribution under surface drip irrigation (DI) with brackish irrigation water Demonstrate recreations were performed utilizing the HYDRUS-2D/3D show assuming tomato crop in saline soil. Results uncovered that the impact of the water system administration on wetting designs varied by the soil's hydraulic properties, while the impact of the underlying soil dampness content vanished following a couple of days. The water system administration and beginning soil dampness content qualities did not show any noteworthy impact on soil saltiness conveyance. Higher soil saltiness happened along the soil surface before the finish of the simulation end time. [14] predicted water dispersion profiles through various soil writes for various conditions and evaluate the appropriation profiles regarding primary qualities of soil and producer. Recreation of water spill out of a solitary surface producer was done by utilizing the numerically-based programming HYDRUS-2D\3D.

The objective of this study was to predict an equation to determine the wetted radius and depth for two Iraqi soil types cultivated with two different types of crops.

2. Materials and Methods

2.1.Numerical Model

Water transports in the soil because of potential angle and toward diminishing potential. The hypothesis of unsaturated stream depended on the supposition that the release of water per unit zone opposite to the heading of stream was specifically relative to the potential slope. The Richards' condition driving the water spill out of a point source through a fluidly immersed permeable media, the condition can be composed in axisymmetric coordinates ([15]; and [16]:

$$\frac{\partial \theta}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left[rK(h)\frac{\partial h}{\partial r}\right] + \frac{\partial}{\partial z}\left[K(h)\frac{\partial h}{\partial z}\right] - \frac{\partial K(h)}{\partial z} - S(h) \quad \text{... (1)}$$

where θ = soil moisture content (L^3L^{-3}), t = time (T), h = pressure head of soil water, (L), r = radial (horizontal) coordinate, (L), z = vertical coordinate (upward direction is positive), (L), K (h) = unsaturated hydraulic conductivity, (LT^{-1}), and S (h) = a sink term that explain the root water uptake expressed as a water volume that removed from a unit volume of soil per unit time, (L^3/L^3T).

The soil moisture retention was modeled using van Genuchten equation [17],

$$\theta(h) = \begin{cases} \theta_r + \frac{(\theta_s - \theta_r)}{(1+|\alpha h|^n)^m} & h < 0 \\ \theta_s & h \geq 0 \end{cases} \quad \text{... (2)}$$

$$S_e = \frac{\theta - \theta r}{\theta s - \theta r} = \frac{1}{(1+|\alpha h|^n)^m},\ m = 1 - 1/n \quad \text{... (3)}$$

where S_e = effective soil moisture content, dimensionless, θ_r = residual soil moisture content, (L^3L^{-3}), θ_s = saturated soil moisture content, (L^3L^{-3}), α = inverse of the air-entry value, (L^{-1}), and n = pore size distribution index, dimensionless.

[17] described the hydraulic conductivity by using the closed form equation, which combines the analytical expression (Eq. 2) with the pore size distribution model of [18]:

$$K(h) = K_s S_e^{0.5}\left[1 - (1 - S_e^{0.5/m})^m\right]^2 \quad \text{... (4)}$$

where K_s = saturated hydraulic conductivity, (LT^{-1}).

The sink term S (h) was computed using the Feddes model (Feddes et al. 1978) adapted for a radially symmetric problem [16]:

$$S(h) = \alpha(h) S_p \quad \text{... (5)}$$

$$S_p = \beta(r, z) A_T T_p \quad \text{... (6)}$$

$$\beta(r, z) = \left[\left(1 - \frac{z}{z_m}\right)\right] e^{-\left(\frac{p_z}{z_m}|z^* - z|\right)} \quad \text{... (7)}$$

where S = actual root water uptake rate, during no stress period, ($L^3L^{-3}T^{-1}$), S_p = potential root water uptake rate, ($L^3L^{-3}T^{-1}$), α (h) = a dimensionless water stress response function of the soil water pressure head varies between 0 and 1 [19], as show in Figure (1), β (r, z) = a function for describing the spatial root distribution [20] (-), z_m = the maximum rooting lengths in the z-direction, (L), z = distances from the origin of the plant in the z- direction, (L), p_z = empirical parameters, (-), z^* = empirical parameters, (L), T_p = the potential transpiration rate, (LT^{-1}), and A_T = the surface area associated with the transpiration process, (L^2).

$$A_T = \pi (r * \%\ \text{wetting})^2 \quad \text{... (8)}$$

where r = radius of infiltration surface area, (L). The percentage of wetting equal to 40% was considered for two soil types.

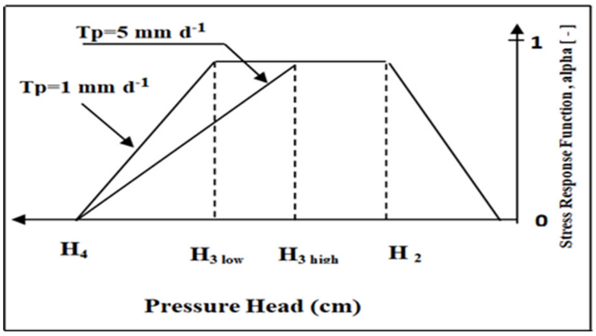


Fig. 1. Schematic representation of dimensionless sink-term variable alpha as a function of soil water pressure head, H.

The HYDRUS-2D requires separating evapotranspiration rate in to evaporation and transpiration rate. The transpiration rate for the five crops was considered to be invariable with time for all runs and equal 4 mm/day [16], and the evaporation rate was determined based on field capacity and welting point according to FAO-56 [21]:

$$TEW = (\theta_{fc} - 0.5\,\theta_{wp})\,Z_e \quad \text{... (9)}$$

where TEW = totally evaporated water, (L), θ_{fc} = soil water moisture at field capacity, (L^3L^{-3}), θ_{wp} = soil water moisture at wilting point (L^3L^{-3}), and Z_e = effective depth of the surface soil, (L).

2.2.Initial and Boundary Conditions

Since water spill out of a surface-point source was two-dimensional axisymmetric, the simulation of the domain should be half in HYDRUS-2D [22]. The single surface emitter was set at the upper corner in the left-hand of the domain close to plant as shown in Figure (2). Consequently, the recreated even measurement of the wetting design speaks to half of the wetted distance across, as show in Table (1); the EF-Mesh was 2 cm. The output of the HYDRUS-2D model for the simulation time was:

1) Wetted width, r, in cm.
2) Wetted depth, z, in cm.

The flux boundary along the emitter was considered to be a constant flux and zero for the sides (left and right) and along the upper surface area, and assumed the bottom as free drainage boundary as show in Figure (2). The radius of the constant flux boundary had been calculated by assuming the flow rate per unit area equal to the soil saturated hydrulic condictivity, when the pressure head was assumed to be zero [23]:

$$q_f = \frac{Q_e}{A} = K_s \quad \dots (10)$$

where Q_e = flow rate of emitter, (L^3T^{-1}), A = saturated surface area = πr_e^2 (L^2), q_f = flux per unit area, (LT^{-1}), and r = radius of infiltration surface area.

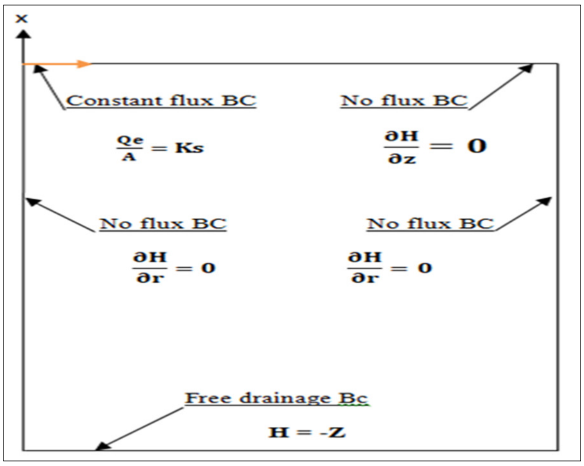


Fig. 2. Schematic representing of the boundary conditions used in all the numerical simulations.

Table 1,
The domain of the simulation.

Soil Texture	Type of crop	Wide domain (cm)	Deep domain (cm)
Silty clay loam	Potato	100	150
Silty clay loam	Cauliflower	100	150

The percentage values of the soil separated for three layers every layer 30 cm ,first layer was selected becouse the roots wasn't pass the second layer and the field capacity and wilting point was determined for the first layer only. Table (2) show the percentage of soil separated and soil texture for the first layer. The simulation was done by using two types of soil texture classified according to USDA soil texture triangle cultivated with crops (cauliflower, potato). The soil characteristics of the soil types were shown in Table (3). The wetting patterns for the soils were predicted at every thirty minute for a total irrigation time equal to 3 hr. Emitter discharges of 0.5, 1, 2, 3, and 5 l/hr were used to simulate the wetting patterns. Five initial volumetric soil moisture contents were used ranged between field capacity and wilting point; the values of initial soil moisture content were shown in Table (4). Fifty simulations runs of the basic were analysis conducted.

Table 2,
Percentage values of the sand, silt, and clay and location for the soil types.

Location	Soil Texture	Sand %	Silt %	Clay %	θ_{fc}	θ_{wp}
Babel	Silty clay loam	12	58	30	0.36	0.17
West Baghdad	Silty clay loam	9	59	32	0.35	0.15

θ_{fc}: Soil moisture content at field capacity, (cm^3/cm^3),
θ_{wp}: Soil moisture content at wilting point, (cm^3/cm^3).

Table 3,
Hydraulic parameters of the two soils texture.

Texture Class	K_s	θ_r	θ_s	α	n
Silty clay loam	0.499	0.085	0.464	0.007	1.535
Silty clay loam	0.488	0.089	0.473	0.008	1.515

θ_r: Residual water content, (cm^3/cm^3)
θ_s: Saturated water content, (cm^3/cm^3)
K_s: Saturated hydraulic conductivity, (cm/hr.)
α: Empirical factors, **(-)**
n: pore size distribution index, (-).

Table 4,
Values of the initial volumetric soil moisture content.

Soil texture	Initial soil moisture content (cm^3/cm^3)				
Silty clay loam	0.19	0.20	0.25	0.30	0.33
Silty clay loam	0.17	0.20	0.25	0.27	0.3

The root depth for potato and cauliflower were 18, and 20 cm, respectively, and all in mid-season. Root water uptake parameters suggested by [19] were described in detail in the HYDRUS technical manual. Water uptake was assumed to be zero close to saturation (i.e. wetter than some arbitrary "anaerobiosis point" P0). Root water uptake was also zero for (negative) pressure heads less than the wilting point (P3). Water uptake was considered optimal between pressure heads Popt and P2, whereas for pressure heads between P2 and P3 (or P0 and Popt) water uptake decreases (or increases) linearly with pressure head, Table (5) show the parameters for the plants used in this research.

Table 5,
Values of the root water uptake parameters.

parameters	Plant type	
	Potato	**Cauliflower**
P0 (cm)	-10	-10
POpt (cm)	-25	-25
P2H (cm)	-300	-600
P2L (cm)	-500	-700
P3 (cm)	-8000	-8000
r2H (cm/hr)	0.02083	0.02083
r2L (cm/hr)	0.00417	0.00417

The parameters which describing the distribution of spatial root as per the model of [20] for every type and the values of β (z) for HYDRUS model, were shown in Table (6). These parameters were viewed as steady with time, since the present form of HYDRUS-2D does not support a period variable spatial root distribution, although in all actuality the dissemination of spatial root fluctuates progressively with the soil dampness content, the soil kind, the age of the plant, and the location of the emitter [24].

Table 6,
Parameters describing a spatial root distribution for HYDRUS model.

Crop type	z_m, (cm)	z^* (-)	z, (cm)	p_z, (-)	β(z) (-)
Potato	18	1	13	1	0.14
Cauliflower	20	1	10	1	0.12

2.3.Field work

So as to confirm the outcomes that acquired from the execution of the software HYDRUS-2D, conducted the experiments were carried out during the growing season of 2017, to measure the wetted radius. The depth of the roots was determined by visual inspection 18 and 20 cm, respectively, for potato and cauliflower. The emitter discharge was 0.8 l/hr measured by using cylinder as show in Figure (3) and irrigation time was 1.8 hr for potato and initial soil moisture content 0.22, emitter discharge 4 l/hr, and irrigation time was 1.5 hr and initial soil moisture content 0.20 for cauliflower.

Fig. 3. cylinder to measure the emitter discharge.

3. Statistical Analysis

Statistical parameters were utilized to test the error between the outcomes values got from HYDRUS-2D/3D programming and the outcomes values got from the created recipes. These parameters incorporate root mean square error (RMSE) used by [25], the optimal value was approaches to zero, modeling efficiency (EF) has the maximum at 1 when predicted values perfectly match the observed ones [23], a model with EF close to 0 would not normally be considered as a good model, and relative error (selection the maximum error). The root mean square errors, and modeling efficiency, were calculated as follows:

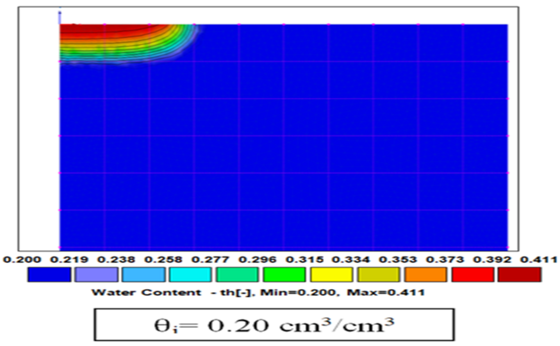
$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(M_i - S_i)^2}{n}} \quad \ldots (11)$$

$$EF = 1 - \frac{\sum_{i=1}^{n}(M_i - S_i)^2}{\sum_{i=1}^{n}(M_i - \bar{M})^2} \quad \ldots (12)$$

where: n = number of values, M_i = values predicted by using HYDRUS-2D software, (cm), S_i = values obtained from the developed formulas, (cm), $\bar{M}$ = mean of values obtained from HYDRUS-2D software, (cm).

4. Results and Discussion

Soil patterns wetted from a point source simulated by using HYDRUS-2D software. The data obtained from the simulations were used to predict the radius and depth of wetted soil as a function of emitter discharge, time of application, initial soil moisture content, and soil type. Two methods were utilized as a part of creating equations to predict the areas of the wetting design. The principal strategy manages each soil independently and includes plotting, fitting, and communicating pertinent relationships. In this method the domain of the wetting pattern was expressed by suitable relationships among pertinent variables. The HYDRUS-2D software was used in the numerical simulations for all modeled scenarios, water flow, and root water uptake was the processes considered in the simulations to predict the wetting patterns for different types of soil. In this research, a number of simulations were done for each type of soil with root water uptake by selecting a given discharge, initial soil moisture content, evaporation, transportation, root water uptake type, and predicting the wetting pattern after each half hour from the beginning time of irrigation for 3 hr. The discharge was then change and the simulation process was repeated. Thereafter the initial soil moisture content was changed and the simulation process was carried out again. In each simulation the predicted radius and depth of wetted soil were recorded. Figure (4) and (5) show the simulation of wetting pattern for silty clay loam soil cultivated with potato with emitter discharge 1 and 3 l/hr, respectively. Tables (7) and (8) show the equations to foresee wetted span and profundity. The second technique additionally treated each soil independently however used mechanized programming; a different relapse examination was utilized to create observational equations to foresee wetted range and profundity. For each kind of soil, the data obtained by applying HYDRUS-2D programming for the various discharge of emitter, initial soil moisture content, and times were utilized to lead a numerous relapse investigation. The item entitled STATISTICA Version 12 was used to lead the examination. The item relies upon streamlining the framework to find the best-fit condition for a given game plan of conditions. By doing thusly an exploratory condition was obtained to envision wetted range and significance for each kind of soil as perceived by the saturated hydraulic conductivity. Tables (8) and (10) demonstrate the created recipes which express the wetted radius and depth; the tables in like manner demonstrate the estimations of the statistical parameters.



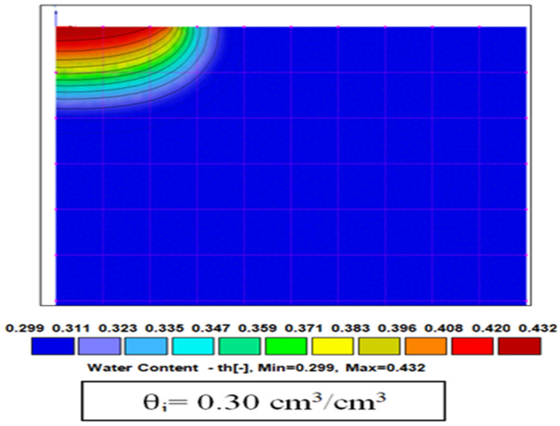


Fig. 4. Simulation of wetting pattern from a surface emitter for the silty clay loam soil texture, with uptake by potato plant, with 1.0x1.5 m domain, θ_i=0.20 and 0.30 by volume, and discharge 1 l/hr after 3 hr.

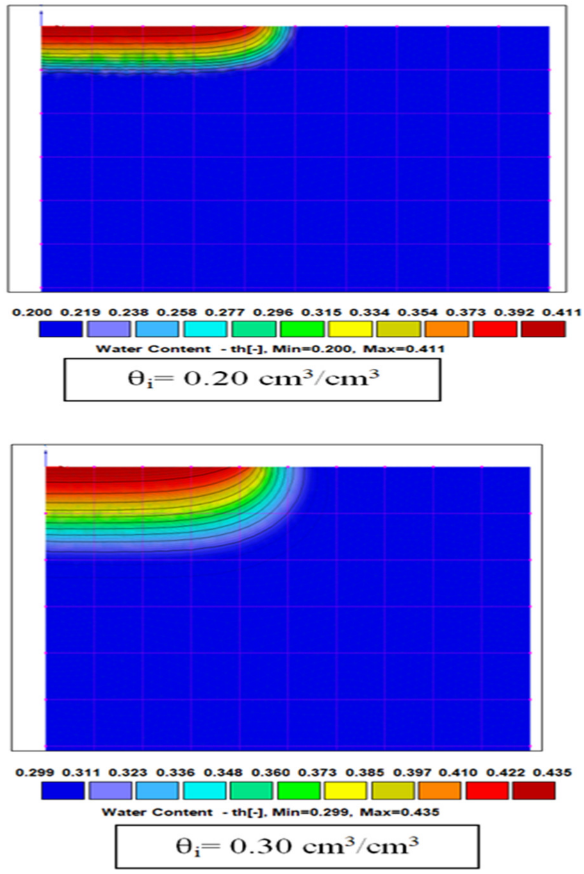


Fig. 5. Simulation of wetting pattern from a surface emitter for the silty clay loam soil texture, with uptake by potato plant, with 1.0x1.5 m domain, θ_i=0.20 and 0.30 by volume, and discharge 3 l/hr after 3 hr.

Table 7,
Empirical formulas to expect wetted radius for two types of soil (First method).

K_s (cm/hr)	Plant type	Wetted Radius, r (cm)	EF	RMSE (cm)	Max. Error, (%)
0.499	Potato	$44.343\ \theta_i^{0.2426}\ Q^{0.420}\ t^{0.485\ \theta_i^{1.1093}\ Q^{-0.400}}$	0.99	1.05	5.40
0.488	Cauliflower	$39.379\ \theta_i^{0.1663}\ Q^{0.440}\ t^{0.500\ \theta_i^{1.1855}\ Q^{-0.410}}$	0.99	0.88	5.07

Table (8),
Empirical formulas to expect wetted depth for two types of soil (First method).

K_s (cm/hr)	Plant type	Wetted Depth, z (cm)	EF	RMSE (cm)	Max. Error, (%)
0.499	Potato	$90.535\ \theta_i^{1.674}\ Q^{-0.020}\ t^{1.7651\ \theta_i^{0.9707}\ Q^{0.010}}$	0.95	1.42	31.19
0.488	Cauliflower	$36.753\ \theta_i^{1.1151}\ Q^{0.01}\ t^{0.7591\ \theta_i^{0.1967}\ Q^{-0.010}}$	0.97	0.64	13.68

Table 9,
Empirical formulas to expect wetted radius for two types of soils having different saturated hydraulic conductivity (Second method).

K_s (cm/hr.)	Plant type	Wetted Radius r, (cm)	EF	RMSE (cm)	Max. Error, (%)
0.499	Potato	$42.592\ t^{0.077}\ Q^{0.409}\ \theta_i^{0.206}$	0.99	1.17	13.15
0.488	Cauliflower	$38.600\ t^{0.064}\ Q^{0.423}\ \theta_i^{0.146}$	0.99	1.02	13.05

Table (10),
Empirical formulas to expect wetted depth for two types of soils having different saturated hydraulic conductivity (Second method).

K_s (cm/hr)	Plant type	Wetted Depth z, (cm)	EF	RMSE (cm)	Max. Error, (%)
0.499	Potato	$103.785\ t^{0.584}\ Q^{0.017}\ \theta_i^{1.779}$	0.98	0.83	12.45
0.488	Cauliflower	$46.087\ t^{0.579}\ Q^{0.003}\ \theta_i^{1.274}$	0.98	0.62	15.63

4.1 The Comparing

Comparing the results of the wetted radius obtained by using HAYDRUS-2D software with those measured in the field, the measure was directly after the end time of irrigation. Table (11) shows the result of such comparison for potato and cauliflower, the measure was directly after end time of irrigation. The relative error was used to test the discrepancy between measured and calculated values of wetted radius. The relative error was calculated as follows:

$$\text{Error } \% = 100\left(\frac{M-S}{M}\right) \quad \ldots (11)$$

where: M = measured wetted radius, (cm) and S = simulated wetted radius, (cm).

The values of relative errors were shown in Table (11) from which it can be seen that the values of the relative error for the obtained results from HYDRUS-2D, and formulas were differ appreciably from measured values, this is mostly because of the approximations utilized as a part of building up the recipes. This disparity was fundamentally in light of the fact that those models were inferred for a given estimations of saturated hydraulic conductivity.

Table 11,
Comparison of measured and simulated wetted radius by HYDRUS-2D.

Soil type	Plant type	Emitter's discharge *(l/hr)*	Time, *(hr)*	Wetted Radius r, *(cm)*				The Relative error, *(%)*		
				Measured[1]	HYDRUS[2]	Simulated[3]	Simulated[4]	HYDRUS	Simulated[3]	Simulated[4]
Silty clay loam	Potato	0.8	1.8	33	30.09	30.84	30.57	8.82	6.55	7.36
Silty clay loam	Cauliflower	4	1.5	60	55.32	54.74	54.98	7.8	8.77	8.37

[1]measured wetted radius from field work.
[2]simulated wetted radius by using HYDRUS-2D software.
[3]simulated wetted radius by using formulas in Table 7
[4]simulated wetted radius by using formulas in Table 9

After End Time of Irrigation

By using variable flux (variable flux 1) instead of constant flux of boundary conditions in HYDRUS-2D to know the soil moisture distribution after end time of irrigation, Figure (6) show the actual root water uptake flux at the end time of irrigation for 48 hr. the root water uptake flux increased from 0.0123 to 0.0135 cm/hr in silty clay loam soil for cauliflower plant, and 0.0142 to 0.0146 cm/hr in silty clay loam for potato plant, the increasing was mainly due to soil type, the fine-textured soil (silty clay loam) has large capillary force and need more time to transfer water in soil layer.

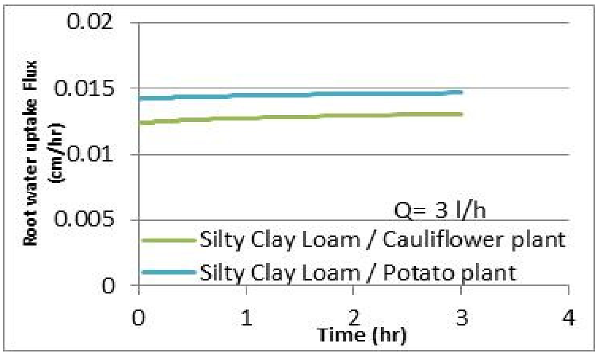
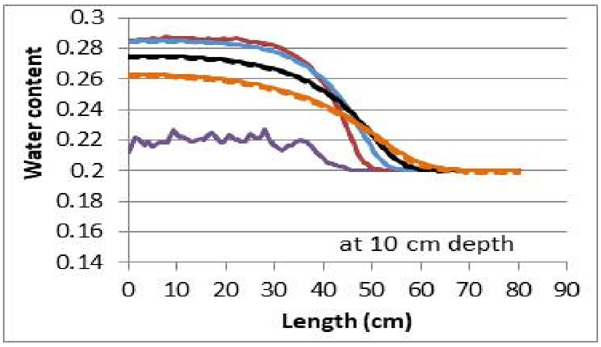
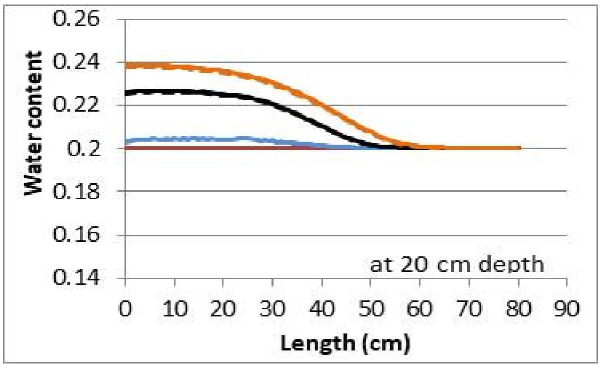


Fig. 6. Temporal variation in root water uptake for different soil types after end time of irrigatin.

The Effect of root uptake by crop after end time of irrigation on soil moisture distribution.

In this part, two simulation runs (variable flux 1) was conducted instead of constant flux of boundary conditions. The results of numerical simulations for silty clay loam soil for bare and vegetated soils, soil moisture content profiles along the horizontal and the vertical cross sections for five output times with an increasing time stage, 3, 6, 12, 24, and 48 hr after 3 hr of irrigation were showed in Figure (7). The horizontal soil moisture content distributions was carried-out at three horizontal cross sections at depth of 10, 20, and 30 cm from the emitters for the bare vegetated soil silty clay loam, with initial soil moisture content 0.20 cm^3/cm^3, at emitter's discharge 3 l/hr after end of irrigation time (3 hr). The different in soil moisture content between bare and vegetated soil were notice because the soil was fine-textured and the ability of saving water was large. Figure (8) shows the vertical soil moisture content distribution at three vertical cross sections at distance 10, 20, and 30 cm from the emitter for the bare and vegetated soil silty clay loam. The soil water distributions along the cross section were large but decreased as time passes on and pull away from the emitter.





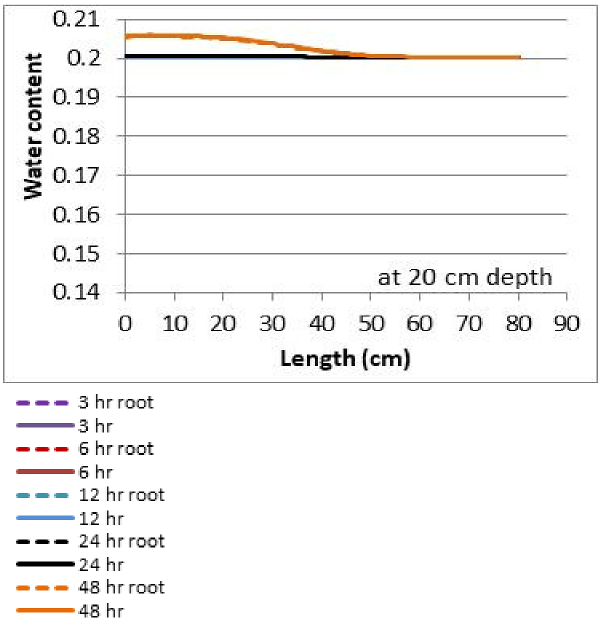


Fig.7. Soil moisture content profiles at different depth from the emitter point source in silty clay loam soil for a bare and vegetated (cauliflower), for different time at emitter dicharge 3 l/hr.

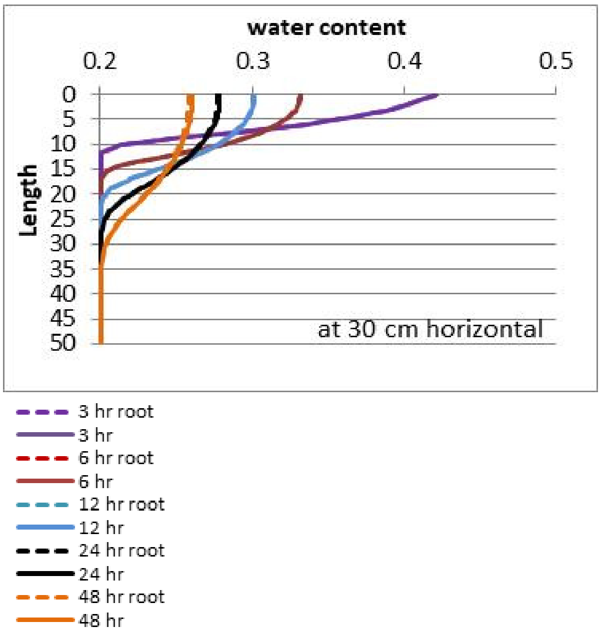
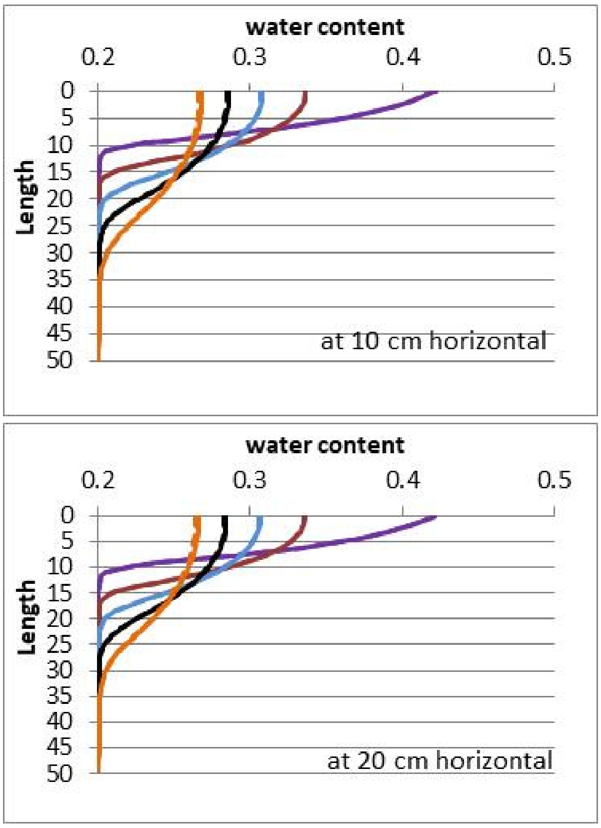


Fig. 8. Soil moisture content profiles at different distance from the emitter point source in silty clay loam soil for a bare and vegetated (cauliflower),for different time at emitter dicharge 3 l/hr.



5. Conclusion

Based on the obtained results of this investigation, the following conclusions were listed:

1. The estimated wetted radius and depth simulated by HYDRUS model were in good agreement with the measured values. This indicates that this model was reliable for predicting wetted area from a trickle point source.
2. The wetted area was independent of the presence and absence of plant.
3. The distribution of moisture content was depends on the presence of plant and it decrease in silty clay loam soil.
4. The type of soil effect on the wetted area and soil moisture content distributions.
5. The water movement in silty clay loam soils was governed by the capillary forces throughout the entire period of irrigation. Gravity force has no significant effect on the movement of the water in silty clay loam soils.
6. The general moisture content distribution in the soil profiles after 48 hour of re-distribution showed that the moisture content decreases with distance in both directions for silty clay loam soils.

Notation

θ	soil moisture content, L^3/L^3
θ_i	initial soil moisture content, L^3/L^3
θ_r	residual soil moisture content, L^3/L^3
θ_s	saturated soil moisture content, L^3/L^3
t	time, T
h	soil water pressure head, L
r	radial (horizontal) coordinate, L
K (h)	unsaturated hydraulic conductivity, L/T
S_e	effective soil moisture content, dimensionless
n	pore size distribution index, dimensionless
K_s	Saturated hydraulic conductivity, L/T
S	actual root water uptake rate, $L^3L^{-3}T^{-1}$
S_p	potential root water uptake rate, $L^3L^{-3}T^{-1}$
z_m	maximum rooting lengths in the z direction, L
z	distances from the origin of the plant in the z direction, L
p_z	empirical parameters, dimensionless
z^*	empirical parameters, L
T_p	Potential transpiration rate, L/T
A_T	Surface area associated with the transpiration process, L^2
r_e	radius of infiltration surface area, L
TEW	Totally evaporated water, L
θ_{fc}	soil water moisture at field capacity, L^3/L^3
θ_{wp}	soil water moisture at wilting point, L^3/L^3
Z_e	effective depth of the surface soil, L
Q	flow rate of emitter, L^3/T
A	saturated surface area, L^2
q_f	flux per unit area, L/T
h	soil water pressure head, L
ET_o	Reference crop evapotranspiration, L/T
ET_c	crop evapotranspiration, L/T
K_c	crop coefficient, dimensionless
r	Wetted radius, L
z	Wetted depth, L
α	inverse of the air-entry value, 1/L
α (h)	water stress response function of the soil water pressure head, dimensionless.
β (z)	a function for describing the spatial root distribution, dimensionless.
ρ	Average apparent specific gravity, dimensionless.

Acknowledgements

Special thanks are extended to Dr. Mohammad N. Elnesr Chair of Water Research, King Saud University, Saudi Arabia, for his invaluable help and support in providing HYDRUS software

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نمذجة عددية لجريان الماء في تربة غير مشبعة من نظام ري بالتنقيط مع الاخذ بنظر الاعتبار التبخر والنبات

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الخلاصة

نُفذ هذا البحث لدراسة تأثير النباتات على جبهة الترطيب لأنواع مختلفة من الترب في العراق، وللتنبؤ بمعادلة لحساب نصف القطر المبتل والعمق لنوعين مختلفين من الترب المزروعة بأنواع مختلفة من النباتات، وتنبئ انماط الترطيب كل ثلاثين دقيقة لوقت ري اجمالي يساوي ٣ ساعات. تم استخدام تصاريف منقطات ٠,٥، ١، ٣،٢ و ٥ لتر/ساعة لمحاكاة انماط الترطيب واستخدام خمسة محتويات رطوبية ابتدائية للترب تتراوح بين السعة الحقلية ونقطة الذبول. واجريت محاكاة تدفق المياه من منقط مفرد باستخدام برنامج HYDRUS-2D/3D، إصدار ٢,٠٥. تم استخدام طريقتين في تطوير المعادلات للتنبؤ بانماط الترطيب، الطريقة الاولى تتعامل مع كل تربة على حدة وتتضمن على التخطيط المناسب، والتعبير عن العلاقات ذات الصلة، والحد الأقصى للخطأ لم يتجاوز ٣١,٢٪، وكفاءة النمذجة لم تقل 0.95، ولم يتعدى خطأ الجذر المربع المربع ١,٤٣ سم لنصف قطرها وعمقها المبلل. أما الطريقة الثانية فقد تم التعامل مع كل تربة على حدة ولكنها استخدمت برامج حاسوبية تستخدم تقنيات الانحدار المتعددة، ولم يتجاوز الخطأ الأقصى ١٥,٦٤٪ لا تقل عن ٠,٩٨، ولم يتجاوز خطأ الجذر المتوسط المربع ١,١٨ سم لنصف القطر والعمق المبلل .أجريت تجربة حقلية لقياس نصف القطرالمبتل للتحقق من النتيجة التي حصل عليها البرنامج HYDRUS-2D ، وتم مقارنة قيم القياس مع المحاكاة من قبل البرنامج. نتائج المعادلات للتعبير عن نصف القطر المبتل والعمق تتمثل بوقت الري، وتصريف المنقطة، والمحتوى الرطوبي الابتدائي للتربة. وبعامة يمكن استخدامها بدقة جيدة بالاعتماد على النتائج التي تم الحصول عليها.