SOIL MOISTURE DISTRIBUTION IN SANDY SOIL UNDER DRIP IRRIGATION SYSTEM USING NEUTRON SCATTERING METHOD

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ABSTRACT

This work aims to study soil moisture behavior in sandy soil under drip irrigation system in order to control the management in sandy soil using neutron scattering technique.

Studying soil moisture distribution through the soil profile is important to management the irrigation water, to achieve the maximum benefit from irrigation water. To achieve this aim, an experiment was carried out at the farm of Soil and Water Department, Nuclear Research Center, Atomic Energy Authority, Inshas (latitude longitude 30° 19̀ N longitude 31° 27̀ E), during onion growing season (2008/2009). Drip irrigation system was used for applying irrigation water. The uniformity of emitters' water application was checked to judge the system.

Data showed that it's possible to use the combination work between neutron scattering technique and soil moisture retention models to study the direction of soil water movement within sandy soil profile. As well as predicting some soil plant concepts (i.e., active rooting depth and depth of collective active roots for water absorption); these concepts used to determine evapotranspiration, drainage rate and active rooting zone. Detecting total hydraulic potential within the wet area around the dripper along dripper lines and between lateral lines helps to study the behavior of soil moisture values within soil profile. The obtained data show also that the actual evapotranspiration of onion plant differs from site to site in wet area according to soil moisture availability. Surfer computer program also shows soil profile can be classified into different areas after and before irrigation within the wet area around drippers.

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The combination work between neutron probe, soil moisture tension models and. Surfer computer program shows study the horizontal and vertical movement of soil water in the wet area around the dripper and obtaining couture lines of soil moisture within the wet area. .

Keywords: *Neutron scattering technique, Active rooting depth, soil water distribution, Actual evapotranspiration, Drip irrigation system*

INTRODUCTION

Neutron scattering technique plays an important role in studying water behavior in soil profile; the advantage of this technique is due to the determining an accurate results of soil moisture in the deeper soil depth without soil destructive. Neutron moisture meter could also used to determine many of soil properties such as field capacity by measuring the soil moisture content, on a volume basis versus time in hours after wetting **Burrows et al (1958)**.

Neutron moisture meter can be also subdue to determine some static and dynamic properties of soil such as soil water storage, soil water retention curves and soil hydraulic conductivity **IAEA 2003**.

Monitoring soil moisture in the crop root zone would allow better management of the water application to meet crop requirement **Zedan (2005)**.

Proper irrigation water management consists of many components. Proper irrigation system design, accurate irrigation scheduling etc. Proper irrigation management help to maximize water use efficiency, yield and minimizing production cost.

Mateen et al (2005) studied the effect of irrigation intervals on growth and yield of onion 5,10,15,20 days in addition to the control treatment in sandy loam soil; they found the 5 days irrigation intervals treatment was the better irrigation interval compared with the other treatments in plant growth and onion yield.

Irrigation scheduling is the decision of when and how much water to apply to a field **Brouwer et al (1989)**; the purpose of irrigation scheduling is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level.

Irrigation scheduling methods differ by the irrigation criterion or by the method used to estimate or measure this criterion.

The amount of water that should be applied with each irrigation depend on the soil and the amount of water it can retain for plant use, referred to available water, The amount of water removed from the soil by the plant since the last irrigation. Also irrigation should begin when the crop comes under stress severe enough to reduce crop yield or quality. The level of stress that will cause a reduction in crop yield or quality depends on the kind of crop and its stage of development; the level varies during the growing season as the crop matures.

Irrigation scheduling requires knowledge of the soil, the soil water status, the crop, the status of crop stress and the potential yield reduction if the crop remains in a stressed condition **Robert Evans et al (1996)**.

Hanson et al (2000) pointed that there are two main ways to schedule irrigation, the first one by replacing crop evapotranspiration (ETc) fractions according to a soil water balance, or by triggering irrigation according to water content status of the soil and allowable depletion levels, They also added the ways that is depend on water content may be more practical and easy to use for alfa alfa and pasture producers.

Juan Enciso et al (2009) used different scheduling strategies and water stress level to evaluate yield and quality of onion under subsurface drip irrigation system, the treatments were by maintains the soil moisture content at -20 K pa, -30 K pa and -50K pa and the other strategy was to replace 100 %, 75% and 50 of crop evapotranspiration , They found The higher total yield and Jumbo onion size were obtained when the soil moisture was kept above -30 K pa and also the yield were not affected when water reduce from 100 % to 75 % Etc. Soil matric potential (SMP), especially in non-saline soil, is considered a better criterion for characterizing crop soil water availability than Soil water content. Numerous studies using tensiometers to measure SMP and schedule irrigation have been reported **Feng- Xin Wang et al (2007)** examined the effect of five soil matric potential treatments under drip irrigation conditions for potato plants.

Active root depth is soil depth which separates between roots and gravitational effects. The active root depth increase during the growing season at the crop develops. It begins at zero at planting and increases to maximum with time.. ARD could be calculated from the in situ measurements of total hydraulic potential at hydraulic gradient equal zero (dH/dZ=0). (**sallam and El-Gendy 1999**). So this depth is very important for separating between the lost water by drainage and evapotranspiration.

The objective of this study is to study the soil moisture distribution under drip irrigation system within the soil profile in sandy soil cultivated by onion using neutron scattering technique.

MATERIALS AND METHODS

The experiment consists of three replicates of irrigation water interval (5 days) to study direction of soil moisture movement; soil moisture depletion of actual evapotranspiration and drainage, active rooting depth, evaporation depth and depth of active roots for water absorption within the soil profile, five neutron access tubes were installed around a dripper (fig1). The soil was cultivated with onion plant.

Some soil determinations were made, Soil matric potential using equation (1) and total hydraulic potential (using equation 2) were determined at the depth according to **El Gendy (2008).**

$$h = -(h_b)\left[\left(\frac{\theta-\theta_r}{\theta_s-\theta_r}\right)^{\left(\frac{-1}{m}\right)}-1\right]^{\left(\frac{1}{n}\right)} \text{--------} (1)$$

$$H = -(-h)\left[\left(\frac{\theta-\theta r}{\theta_s-\theta r}\right)^{\left(\frac{-1}{m}\right)}-1\right]^{\left(\frac{1}{m}\right)} - Z \text{----} (2)$$

Where:

h, is the soil matric potential, mbar

hb, is the air entry suction, mbar

θ r, residual soil moisture, $cm^3\ cm^{-3}$

θ s , saturation point, which equals total porosity

m and n, constants for fitting soil moisture retention curve, and

Z, is the soil depth for measuring total hydraulic Potential, mbar

The soil moisture distribution was estimated by detecting soil moisture values after and before next irrigation within the soil profile. This distribution was carried out within the wet area around dripper or plant by using five access tubes of neutron probe as shown in figs (1&2). Neutron probe used to determine the soil moisture within the wet area at 30, 45, 60, 75 and 90 cm depths. As for the surface layer(0 – 15 cm), the soil water content was determined using gravimetric method

Active root depth (ARD) was estimated by detecting hydraulic potential gradient (at maximum point, dH/dZ = 0) within the soil profile to obtain the soil depth, which separates between evapotranspiration and drainage effects.

ARD was used to calculate ETa and Dr Rates via calculating soil moisture depletion above and below ARD and divided on an irrigation interval, respectively.

Neuron calibration curves for neutron moisture meter at different soil depths were determined, table (1) according to **IAEA (1976)**

Water quantity was applied according soil moisture depletion occurred to 0.6 m depth.

The irrigation water quantity was calculated using the following formula:-

Irrigation water quantity = $(\theta_{f.c} - \theta_{before\ next\ irrigation}) \times (60/100) \times 48 \times 100/85$

Where:

$\theta_{f.c}$ the soil water content at field capacity

θ_{before} the soil water content before irrigation

48 is the experimental area, m^2

PH values were determined in soil suspension (1: 2.5), EC (dS/m) values were determined in the extract of soil paste, soluble anions, were determined in this extract according to **Page, 1982**. Sulfates were calculated by difference, soluble cations, were determined in soil extract according to **Page, (1982)**.

Particle size distribution according to **Jacobs *et al* (1971)**, soil bulk density, total porosity

Table (1) calibration curves for neutron moisture meter at different soil depths of the studied soils.

Soil Depths	Regression equation	Coefficient of determination (R^2)
30	θ =14.71 C.R -1.773	0.992
45	θ =15.63 C.R -2.852	0.954
60	θ =17.89 C.R -3.599	0.917
75	θ =10.80 C.R - 0.931	0.986
90	θ = 25.48 C.R -7.214	0.873

Figure (1) illustrate the locations of accuses tube.

Table (2): Some physical properties of sandy soil.

Soil depth cm	Particle size distribution			Texture class	Bulk density g/cm^3	Total porosity $cm^3\ cm^{-3}$	F.C %	θr* %
	Sand	Silt	Clay					
15	98.13	1.40	0.47	Sand	1.78	0.32	8.5	1.90
30	98.73	0.80	0.47	Sand	1.78	0.32	8.5	1.90
45	98.60	0.87	0.53	Sand	1.77	0.33	8.5	1.79
60	98.63	0.87	0.50	Sand	1.77	0.33	8.5	1.78
75	98.57	0.70	0.73	Sand	1.73	0.34	8.4	1.78
90	98.57	0.70	0.70	Sand	1.73	0.34	8.4	1.78

θ r is residual soil moisture content, $cm^3\ cm^{-3}$

Table (3): Some chemical properties of studied soil.

Soil depth cm	Soluble cations (m eq/L)				Soluble anions (m eq/L)				SAR	EC dS/m	PH
	K^+	Mg^{++}	Ca^{++}	Na^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}			
15	0.20	1.0	4.5	2.6	--	3.0	5.1	0.20	1.568	0.68	7.72
30	0.19	1.3	4.4	2.7	--	3.2	5.2	0.19	1.599	0.62	7.76
45	0.19	1.3	4.5	2.6	--	3.2	5.2	0.19	1.527	0.64	7.76
60	0.20	1.5	4.4	2.6	--	3.3	5.2	0.10	1.514	0.67	7.72
75	0.18	1.6	4.0	3.6	--	3.5	5.1	0.78	2.151	0.67	7.77
90	0.18	1.6	4.0	3.5	--	3.5	5.1	0.68	2.092	0.67	7.76

RESULTS AND DISSCUSION

Direction of Soil Moisture Movement

Direction of soil water movement within the soil profile was detected via determination of total hydraulic potential at different soil depths using model 2 using determination of soil moisture contents using neutron probe. The importance of study direction of soil water movement is due to define depths of evaporation, collection of roots for water absorption and active rooting depth (Fig. 3).

By detecting hydraulic gradient (dH/dZ) within the soil profile, it was found (dH/dZ) equals to zero at the maximum and minimum points of the relationship between total hydraulic potential (H, mbar) and soil depth (Z). That means there is no water flux at these points (A, B and C). These points are separate between upward and downward movement. Table (4) includes definitions of all cases for soil water movement directions were occurred within the soil profile via calculation of hydraulic potential gradient (dH/dZ). It is worthy to mention that (dH/dZ) is positive sign when the direction is upward movement and negative sign at downward movement **De Bedoot et al (1967).** So, the direction of soil water movement is upward from 15 to 30, from 60 to 45 and from 75 to 60 cm depths. Downward movement was occurred from 30 to 45 and from 75 to 90 cm depths. . The upward movement from 30 to 15 cm depth is due to evaporation from the surface soil layer where the surface evaporation decreased the total hydraulic potential at 15 cm depth(-1026 mbar), whenever it was at 30 cm was high (-709 mbar), so, the direction of soil water movement was upward. The collective roots for water absorption are at 45 cm depth. The soil layer (30 to 72 cm depth) from A to C points is considered the layer of water feeding to active roots for water absorption, where, at B point (45 cm depth) is the lowest water potential (-1032 mbar) rather than at A point (-709 mbar) and C point (-460 mbar). This due to water absorption by active roots, which causes decreasing in water potential, so, direction of soil water movement directed to B point (45 cm depth) and from up (at 30 cm depth). At 72 cm depth (C point) there was a level separates between gravitational force (down ward movement below this depth) and Roots effect (upward movement this level), this soil depth was called active rooting depth (ARD)

ARD is important to classify the soil moisture depletion to two components, the first is due to Evapotranspiration effect (above ARD to the soil surface) and the second is due to gravitational effect (below ARD) it is called water drainage.

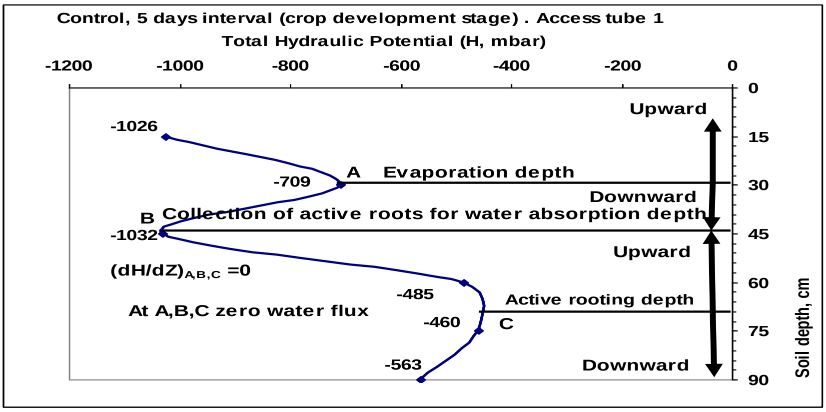


Fig.(2): Direction of soil water movement within the soil profile at site 1 (access tube 1).

Table (4): Calculating gradient of hydraulic potential and direction of soil water movement.

Soil depth	Calculation (dH/dZ)	(dH/dZ) value	Direction of soil water movement
15- 30	(-709-(-1026))/(30-15)	+21.13	Upward movement
30-45	(-1032-(-709))/(45-30)	- 21.53	Downward movement
45-60	(-485-(-1032))/(60-45)	+36.47	Upward movement
60-75	(-460-(-485))/(75-60)	+1.67	Upward movement
75-90	(-563-(-460))/(90-75)	- 6.87	Downward movement

Soil Moisture Distribution

Soil moisture values were determined after and before next irrigation to study the soil moisture distribution within the soil profile. The important studying this distribution is due to for different reasons:-

- Calculating soil moisture depletion, this is due to surface evaporation and transpiration of onion plant.
- Calculating actual evapotranspiration (Water consumptive use of onion plant)
- Calculating soil moisture depletion, this is due to gravitational effect.

- Calculating water drainage rate

Fig.(3): illustrates the soil moisture distribution after irrigation and before next irrigation at irrigation interval 5 days of onion yield. SMD is as affected by Evapotranspiration, which was 13 mm/ 5days and ETa was equals to 2.6 mm/day. This SMD occurred above ARD, but below it SMD was due to drainage effect, which was equals to zero mm/5days, so, drainage rate was zero mm/day too.

Table (3): includes the summarized of soil moisture suction values within active rooting depth, hydraulic parameters and active rooting depth in different sites in wet area around a dripper for 5 days interval. The same Table clears that the soil moisture potential at the dripper (finding roots of onion) reached -732 mbar the highest value resulted from water absorption by active roots. Also, it reached -644 mbar at five site, which resulted increase in actual Evapotranspiration (3.3 mm/day). Generally value of soil moisture potential within the active rooting zone for the five sites in wet area around dripper was -437 mbar for sandy treatment of 5 days interval.

Average of soil moisture depletion (SMD) was due to actual Evapotranspiration was about 12 mm where all sites converged. As for SMD, which was due to drainage reached to 0.38 mm/day thought 5 days interval.

ETa values differed from one site to another site, where it fluctuated from 2 to 3.8 mm/day for the five sites around the dripper with 2.6 mm/day. This indicates that values of ETa change according to soil moisture availability and soil moisture values were variable from site to another within the wet area , so, the degree of soil moisture availability are variable too.

Drainage rate values converged and ranged from 0.1 to 0.2 mm/day within the five sites around the dripper with 0.1 mm/day as average. Ratio of drainage rate to actual Evapotranspiration reached 3.8%, so, ETa is the dominative factor on the soil moisture depletion.

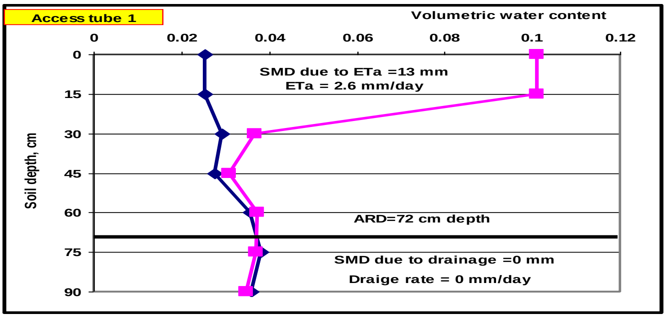


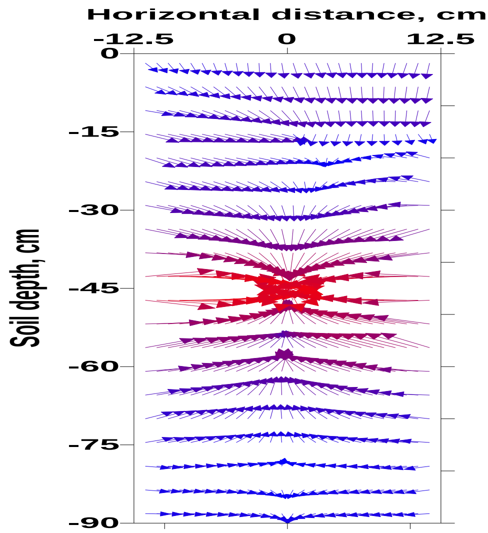
Fig.(3): soil moisture distribution within the soil profile in sandy treatment for onion yield.

Table (3) the summarized of soil moisture suction values within active rooting depth, hydraulic parameters and active rooting depth in different sites of wet area around a dripper .

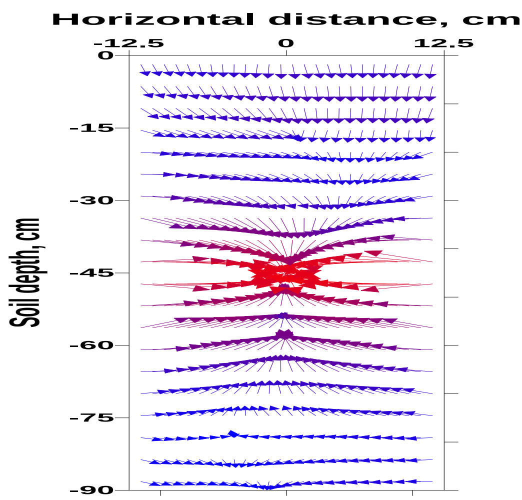
Site No.	h in ARD, mbar	SMD is due to ETa mm	SMD is due to Drainage, mm	ARD, cm	ETa, mm/day	drainage rate, mm/day
1	-385	13	0.3	72	2.6	0.1
2	-732	12	0.3	75	2.5	0.1
3	-420	12	0.5	75	2.4	0.1
4	-385	10	0.0	75	2.0	0.0
5	-644	13	0.8	69	3.3	0.2
Ave.	-437	12	0.38	73.2	2.6	0.1

Direction of Soil Moisture Movement in Two Directions within the wet Area around a Dripper Using the Five sites

Figs. (4 and 5) illustrate the soil depths, which belong to the collection of active roots for water absorption and active rooting depth using average of total potential values after and before next irrigation. These figures represented the direction of water movement along dripper line (Fig. 4) and orthogonal on dripper line (Fig. 5). These figures illustrate the direction of soil water was to 45 cm depth from up and down 45 cm depth. These indicate that finding a collection of active roots for water absorption. Also, they indicate that around 75 cm depth finding active rooting depth, where up and down ward movement around this soil depth. ARD reflects the effect of roots and gravity effects.



Fig(4) Horizontal and vertical direction of soil moisture movement, along dripper line

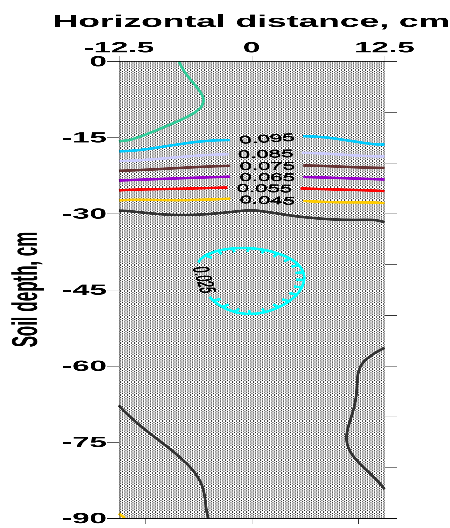


Fig(5) Horizontal and vertical direction of soil moisture movement for vertical direction on dripper line

Soil Moisture Distribution in Two Directions within the Wet Area around a Dripper Using the Five Sites Using Contours Line

Fig.(5) illustrates the contour lines of soil moisture content after irrigation along dripper line . After irrigation the soil moisture values affected by soil moisture values before irrigation resulted from the redistribution of moisture from up and downward movement and water absorption via active roots. So, soil moisture values in 0-15 cm layer reached to 10.5% on the left side of dripper, whenever soil moisture values decreased in 15-30 cm layer from 9.5 to 3.5% under the dripper (finding onion plant) around 45 cm depth, where finding active roots for water absorption. In the deeper soil layer, moisture values decrease to 2.5% around the dripper at 60 and 90 cm depths, that was due to up and downward movement, which resulted from roots and gravity effects.

Fig. (6) Illustrates the contour lines of soil moisture content after irrigation for perpendicular on dripper line. The same trend in along the dripper line was occurred exception in the deeper soil layers (82.5 to 90 cm depth)where the moisture value increased to 4.5 and 5.5% on the right side of the dripper (finding onion plant). That was due to moisture redistribution resulted from the pervious reasons mentioned in along dripper line.



Fig(6) contour lines of soil moisture content , after irrigation ,five days interval along dripper line

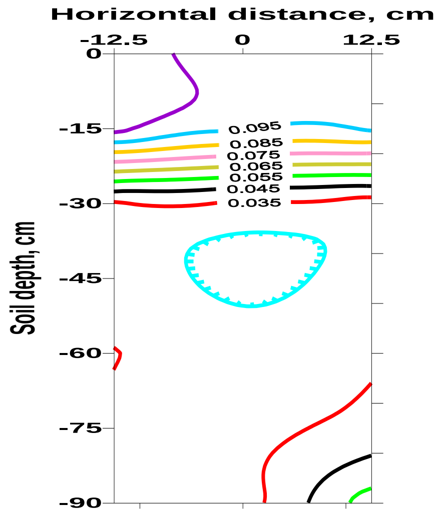


Fig. (7) Contour lines of soil moisture content, after irrigation, for perpendicular on dripper line

Fig.(6) illustrates the soil moisture distribution via contour lines of soil moisture content before next irrigation along dripper line. Soil moisture values ranged from 2.6 to 3.5% in different soil depths. In 0-30 cm layer, moisture values under 12.5 site was 2.6% and extended to 60 cm depth in range 2.6 to 2.9% in the three sites(+12.5, 0, -12.5). Moisture values increased to 3.5% below 60 cm depth and extended to 90 cm depth below 12.5 site and also in the soil layer 67.5 to 90 cm depth.

From the discussed before, decreasing soil moisture values is due to ETa, Drainage rate and the changes in total hydraulic potential resulted from the redistribution process in the soil profile.

Fig.(7) illustrates the contour lines of soil moisture content before next irrigation for the five days interval and for the perpendicular on dripper line. This figure indicates that there was homogeneity in water distribution as in along the dripper lines, where soil moisture values ranged from2.6 to 3.5%.

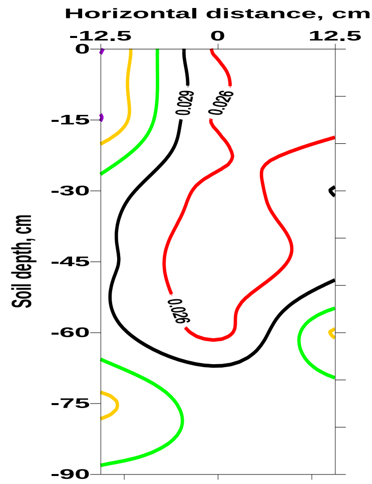
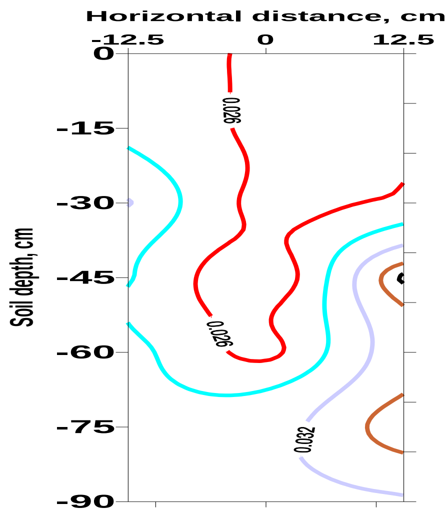


Fig.(8) contour lines of soil moisture content for sandy treatment, before next irrigation ,five days interval for along dripper line



Fig(9) contour lines of soil moisture content for sandy treatment, before next irrigation for the five days interval and for perpendicular on dripper line

Soil Moisture Distribution as Ratio from Field Capacity in Two Directions within the Wet Area around a Dripper Using the Five sites.

Fig.(8) illustrates the soil moisture distribution as a ratio from field capacity after irrigation for the five days interval for along dripper line . 0 -15 and 15-30 m layers represented the highest ratio , where it was over 50% from F.C, as for the rest of the soil profile (30 to 90 cm depth) the ratio ranged from 25 to 50 % from F.C.

Fig.(10) illustrates the soil moisture content distribution as a ratio from field capacity after irrigation for the five days interval for perpendicular on dripper line. This figure illustrates also, the soil moisture distribution as ratio from field capacity took the same trend in along drip lines. This makes sure high homogeneity in two dimensions.

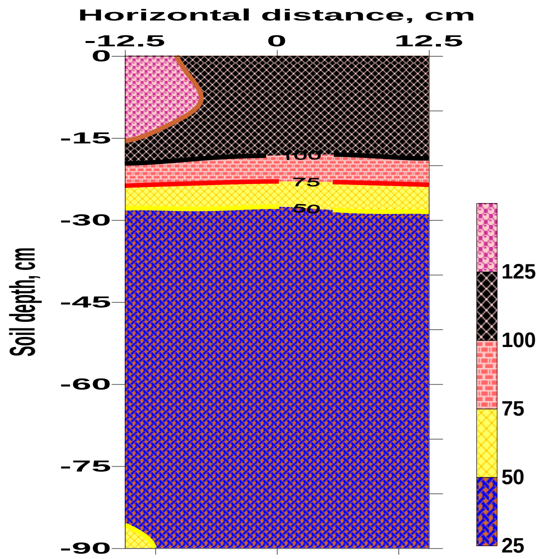


Fig.(10) soil moisture content distribution as a ratio from field capacity for sandy treatment after irrigation for five days interval for along dripper line

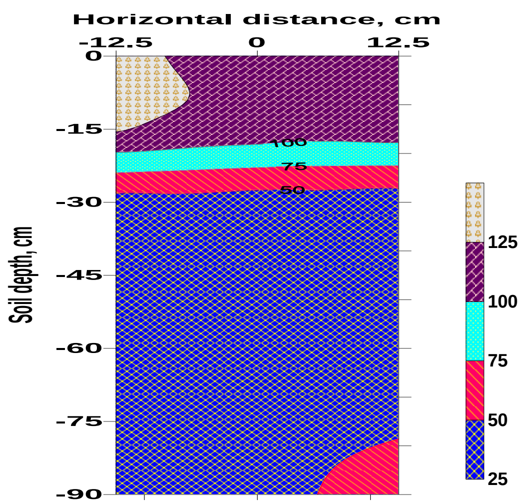


Fig.(11) soil moisture content distribution as a ratio from field capacity for sandy treatment after irrigation for the five days interval and for perpendicular on dripper line

Fig. (12) Illustrates the soil moisture content distribution as a ratio from field capacity before next irrigation for the five days interval for along dripper line. values of soil moisture as ratio from F.C ranged from 27 to 45% and the lowest value ranged from 27 to30% below onion plant (at the dripper , at 0 site) around 45 cm depth resulted from finding active roots for water absorption. The highest value was 45% from F.C was also within the surface soil layer between o and +12.5 sites.

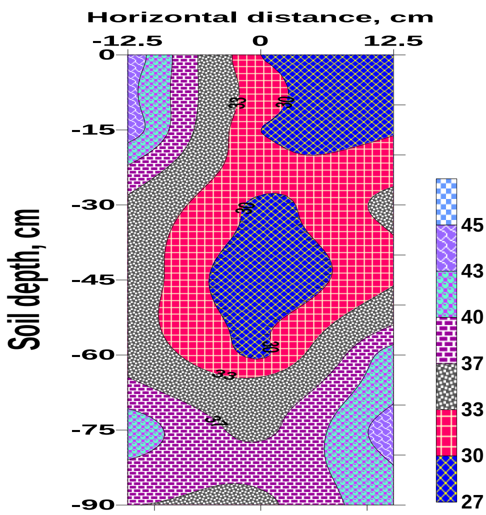


Fig. (12) Soil moisture content distribution as a ratio from field capacity for sandy treatment, before next irrigation for the five days interval along dripper line

Fig. (13) Illustrates soil moisture distribution as a ratio from field capacity before next irrigation for the five days interval for perpendicular on dripper line. The same behavior of water distribution along dripper lines but the lowest ratio was 27 to 30% from F.C between the two sites (0 and +12.5), whenever was along dripper lines 45% from F.C for the same sites.

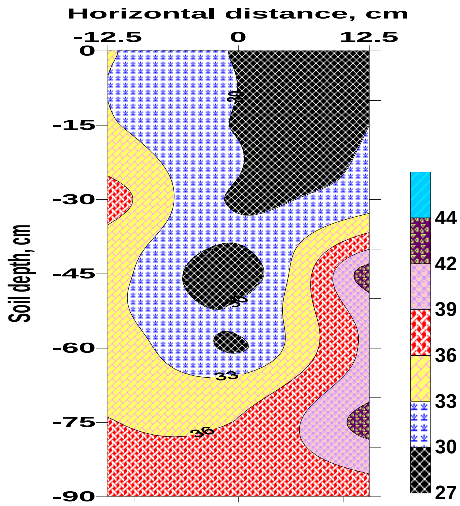


Fig.(13): Soil moisture content distribution as a ratio from field capacity for sandy treatment, before next irrigation for the five days interval for the perpendicular on dripper line

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الملخص العربى

التوزيع الرطوبى فى الاراضي الرمليه تحت نظام الري بالتنقيط باستخدام طريقة تشتت النيترونات

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تهدف هذه الدراسة إلى دراسة سلوك الرطوبة الارضية في الأراضي الرملية تحت نظام الري بالتنقيط وذلك للتحكم في إدارة المياه فيها باستخدام تقنية تشتت النيوترونات.
دراسة توزيع المياه خلال القطاع الاراضى هام فى إدارة مياه الري ، لتحقيق الاستفادة القصوى من مياه الري .اجريت تجربة في مزرعة قسم بحوث الاراضى والمياه ـ مركز البحوث النووية ـ هيئة الطاقة الذرية ، انشاص (خط العرض١٩ ° ٣٠ وخط الطول ٣١ ° ٢٧) ، حيث تم زراعة محصول البصل صنف طنطاوى خلال الموسم الزراعي (٢٠٠٨/٢٠٠٩). تم استخدام نظام الري بالتنقيط لتوزيع مياه الري .
ولقد أظهرت النتائج المتحصل عليها انه يمكن استخدام تقنية تشتت النيوترونات ونماذج منحنيات الشد الرطوبى لدراسة اتجاه حركة المياه داخل القطاع الارضى ، ومنه يمكن ببعض المفاهيم الارضية (مثل العمق الجذرى النشط ، عمق تجمع الجذور لامتصاص الماء) هذه المفاهيم يمكن من خلالها تقدر البخر نتح الفعلى ، معدل الصرف العميق . تقدير الجهد الهيدروليكى الكلى خلال منطقة الابتلال حول النقاطات على طول خط الرى وبين الخطوط ساعد فى دراسة سلوك الماء خلال القطاع الارضى . كما اشارت نتائج الدراسة ايضا أن قيم البخر نتح الفعلى لنبات البصل تختلف من نقطة لأخرى خلال منطقة الابتلال معتمدة على مدى تيسر الرطوبة الارضية . كما ان برنامج السرفر ساعد فى تقسيم القطاع الارضى إلى مناطق مختلفة فى نسة الرطوبة كنسبة من السعة الحقلة قبل وبعد الرى فى المنطقة المبتلة حول النقطاطات . العمل المتكامل بين جهاز تشتت النيترونات ونماذج الشد الرطوبى وبرنامج السيرفر ساعد فى دراسة الحركة الرأسية والافقية للماء الارضى فى منطقة الابتلال حول النقاط معبر عنها كخطوط كنتورية .

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