ULTRA LOW DRIP IRRIGATION EFFECT ON WATER DISTRIBUTION IN SOILS AND SQUASH PRODUCTION

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ABSTRAT

*Ultra low drip irrigation "**ULDI**" system is a new aspect of micro irrigation.It is known as "minute or ultra-low flow- rate" irrigation. This method involves applying water at a very low rate, even lower than the natural soil water intake capacity. Flow rate from minute or ultra-low irrigation system is usually 10 times less than conventional emitters (0.2 L/h).Also; "**ULDI**" gets a continuous moisture and oxygen (air) supply under "Field Capacity" conditions. The first aim of this study is determine the wetting pattern on soil (ClayandSandy) at different application rates (0.25, 0.5, 1.2, and 2 L/h) and different application times. The second aim is investigated in "**ULDI**" effect on squash production. The results showed the following relationships to describe wetted front advance (width "w", depth "d", and diagonal "z"):* $\boldsymbol{\alpha = c\,.\,T^{c_1}.\,K^{c_2}.\,Q^{c_3}}$ ***where α:*** *is in any direction (w, d, or z),* $\boldsymbol{c}$, $\boldsymbol{c_1}$, $\boldsymbol{c_2}$, *and* $\boldsymbol{c_3}$: *are constants that depend on (α) direction,* ***t:*** *is application time (h),* ***K:*** *is hydraulic conductivity (cm/h), and* ***q:*** *is emitter discharge (L/h) . The results of field experiments indicated that the increasing ratio of squash yield when using 0.25 L/h treatment was 41.17 %.*

INTRODUCTION

Micro dripping is an irrigation method that enables a very low flow rate, close to one tenth the flow of ordinary drippers. The nominal flow rate of each micro dripper may be as low as 0.2 L/h and this low flow is resulting with better wetting distribution in the soil. Also;drip irrigation at a rate close to plant water uptake necessitates low application rates (microdrip), which affect soil water regime and

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plant response. Drip irrigation has several advantages over other irrigation methods; e.g., possible damage to the foliage is prevented and because of salts accumulation at the wetting front, soil salinity in the root zone is similar to the initial salinity in the irrigation water when the irrigation is managed properly**(Aragueset al., 1999)**.

Elmesery (2011)illustrated the water movement in soil under micro trickle irrigation system.He indicated that wetted distribution shape in sandy and clay soils at different application times,the distribution of wetted fronts in horizontal and vertical directions were equaled at low application times, until 60 min, but after this time the vertical wetted advance was higher than horizontal distance and the moisture content in pattern core at different micro trickle application rates was equal around field capacity.

Recently,Ultra Low Drip Irrigation systems have been developed that provide emitter discharge rates lower than 0.5 L/h. These systems have been studied most intensively in greenhouses. In micro-drip irrigation, field observations seem to indicate that there is no saturated zone and that the wetted soil volume is greater compared with that for conventional emitter discharges **(Koenig 1997)**.

One of the main factors affecting the distribution pattern of water and solutes in the wetted soil volume with drip irrigation is emitter flow rate. The exceptionally low water application rates (**Ultra Low-Flow Drippers**), in the range of 0.1 – 0.3 L/h per dripper, change the water distribution pattern in the soil and the water-to-air ratio in the wetted soil volume. The horizontal movement is more pronounced than with drippers of conventional flow-rate range. Therefore, water can be applied to shallow root systems with minimized drainage beneath the root-zone. Due to the extremely low water discharge from the emitters, more air remains in the wetted volume, compared with drippers of conventional flow-rate. Extremely low flow-rate drippers are sensitive to clogging because of the narrow water passageway and low flow velocity. There are two technologies to achieve low flow-rate with minimal clogging hazard. One technology is based on conventional button drippers that emit water into a secondary small diameter with 10 – 30 molded or inserted micro-drippers.

In the second technology, conventional drip laterals are used but the water is applied in pulses created by pulsators or by the irrigation controller **(Moshe 2009).**

Awady and Mostafa(1975)studied infiltration of water from tricklers into loamy soils. The study gives details for proper trickle application including puddling, and rate of wet front advance in different directions. Infiltration rate speed was described in terms of hydraulic conductivity, rate of trickling and time in dimensionless power groups.

Lubars and Mead (2008)stated thatadvantages of Ultra Low Drip Irrigation System are: (1) Optimum growth conditions due to the ability to maintain optimum balance of air, water and nutrients in the soil. (2)Minimize leaching of nutrients that occurs with excess water flow. (3) The ultra- low rate system is much cheaper than the common micro-irrigation systems, smaller P.V.C. tubes size reduced horsepower requirements. (4) No water loss though the root zone on very sandy soils. (5) Water could be applied efficiently on shallow soils in hilly areas.

The main objectives of the present work were to study the effect of emitter discharge rates (Ultra Low-Flow Drippers) on wetted pattern in different soils and structure of Ultra Low Drip Irrigation System, and its effect on squash production.

MATERIALS AND METHODS

MATERIALS

Laboratory Experiment

Laboratory Experiments were carried out in the irrigation laboratory, AgriculturalEngineering Department, Al-Azhar University, Nasr City,Cairo. The main objectives of the laboratory experiments were the determination of wetted front advance in different directions (width "w", depth "d", and diagonal "z") in two soils (clay and sandy) with four application rates(q) studied (0.25, 0.5, 1.2, and 2 L/h). The characteristics of clay and sandy soil are determined in table (1) and table (2). PCJ, on-line compact pressure compensated dripper, was used. It was used at pressure of 1 bar as show Fig.(1).

Table (1): Somephysical characteristics of the sandy soil under laboratory study.

Soil depth (cm)	Particle size distribution (%)				Textural class	$CaCO_3$ %	O.M %	Bulk density (g/cm^3)	Hydraulic Conduct-ivity (cm/h)	Field capacity (0.1 atm.) (%)	Permanent wilting percentage (15 atm)	Available soil water (%)
	Coarse sand	Medium Sand	Fine sand	Very fine sand								
0-20	0.12	88.37	10.03	1.48	**S**	1.13	1.93	1.57	9.12	7.85	2.93	4.92
20-40	0.09	85.43	12.95	1.53	**S**	1.17	1.95	1.56	9.27	8.05	2.97	5.08

S = Sand

Table (2): Somephysical characteristics of the clay soil under laboratory study.

Soil depth (cm)	Silt (%)	Clay (%)	Sand (%)	Textural class	$CaCO_3$ %	O.M %	Bulk density (g/cm^3)	Hydraulic conduct-ivity (cm/h)	Field Capacity (0.1 atm.) (%)	Permanent wilting percentage (15 atm)	Available soil water (%)
0-20	15.52	53.36	31.12	**C**	29.87	3.26	1.32	2.85	26.15	11.92	14.23
20-40	12.15	55.22	32.63	**C**	31.23	3.38	1.30	3.04	28.22	12.07	16.15

C = Clay

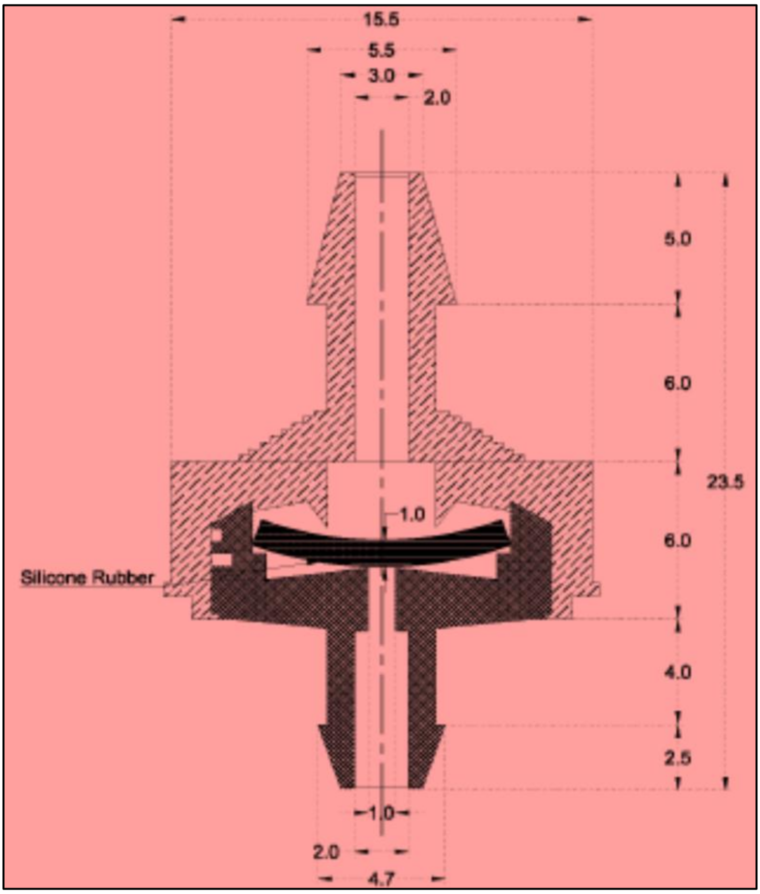


Fig.(1): PCJ, on-line dripper section.

Field Experiment

Squash plants were grown in an experiment field at Agriculture Engineering Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, from 31 May to 8 August, 2011. The soil at the site was loamy sandy as shown in table (3). The field was plowed, disked, and leveled. The field was 14 lines (4 m length and 1 m width), three lines for each discharge rate (0.25, 0.5, 1.2, and 2 L/h). The lateral line spacing was 1 m (one lateral for planting row). Emitter spacing on the lateral line was 0.5 m as shown Fig.(2). The irrigation intervals were 3 days. The plant area, plant length, plant leaves number, and production were measured for each treatment.

Table (3): Some physical characteristics of theloamy sandsoil under field experimentstudy.

Particle size distribution (%)				Textural class	Hydraulic Conduct-ivity (cm/h)		Field capacity (0.1 atm.) (%)	Permanent wilting percentage (15 atm)	Infiltration rate (cm/h)
Coarse sand	Fine sand	Silt	Clay						
48.3	28.8	18.7	4.2	L.S	9.68		12.6	4.13	25.72
Cations (meq/L)				Anions (meq/L)			pH		Ec
Ca	Mg	Na	K	HCo_3	Cl	SO_4			
9.45	6.69	2.43	0.54	4.91	5.1	9.1	7.8		1.91

L.S = Loamy Sand

Class ''A'' evaporation pan

The Class A evaporation pan is circular, 120.7 cm in diameter and 25 cm deep, as in Fig.(3). It is made of galvanized iron. The pan is mounted on a wooden frame platform; it is 15 cm above ground level. The pan must be level. It is filled with water to 5 – 7.5 cm below the rim. The water should be regularly renewed, at least weekly, to eliminateextreme turbidity. The pan, if galvanized, is painted annually withaluminum paint. The coefficient of pan **(k_{pan})** is 0.55. The pan was constructed in the workshop of the Agricultural EngineeringDepartment, Faculty of Agriculture, Al-Azhar University.**(These specifications are as recommended by FAO 1998)**

<u>METHODS</u>

Laboratory Experiment Procedure (Determination of water pattern):

The soil samples were air dried, and put in transparent plastic bags with cylindrical shape of 50 cm diameter and 60 cm depth. The samples were arranged under different discharge drippers (0.25, 0.5, 1.2, and 2 L/h). Drippers were placed on the geometrical center at the top of soil sample. After different application times which were determined before and one hour application times, the wetted width (w) was measured. To determine the wetted depth (d) and wetted diagonal (z), the bag sample was cut and the sample was split from the center accurately and slowly, then wetted depth (d) and wetted diagonal (z) were measured as shown in Fig. (4).

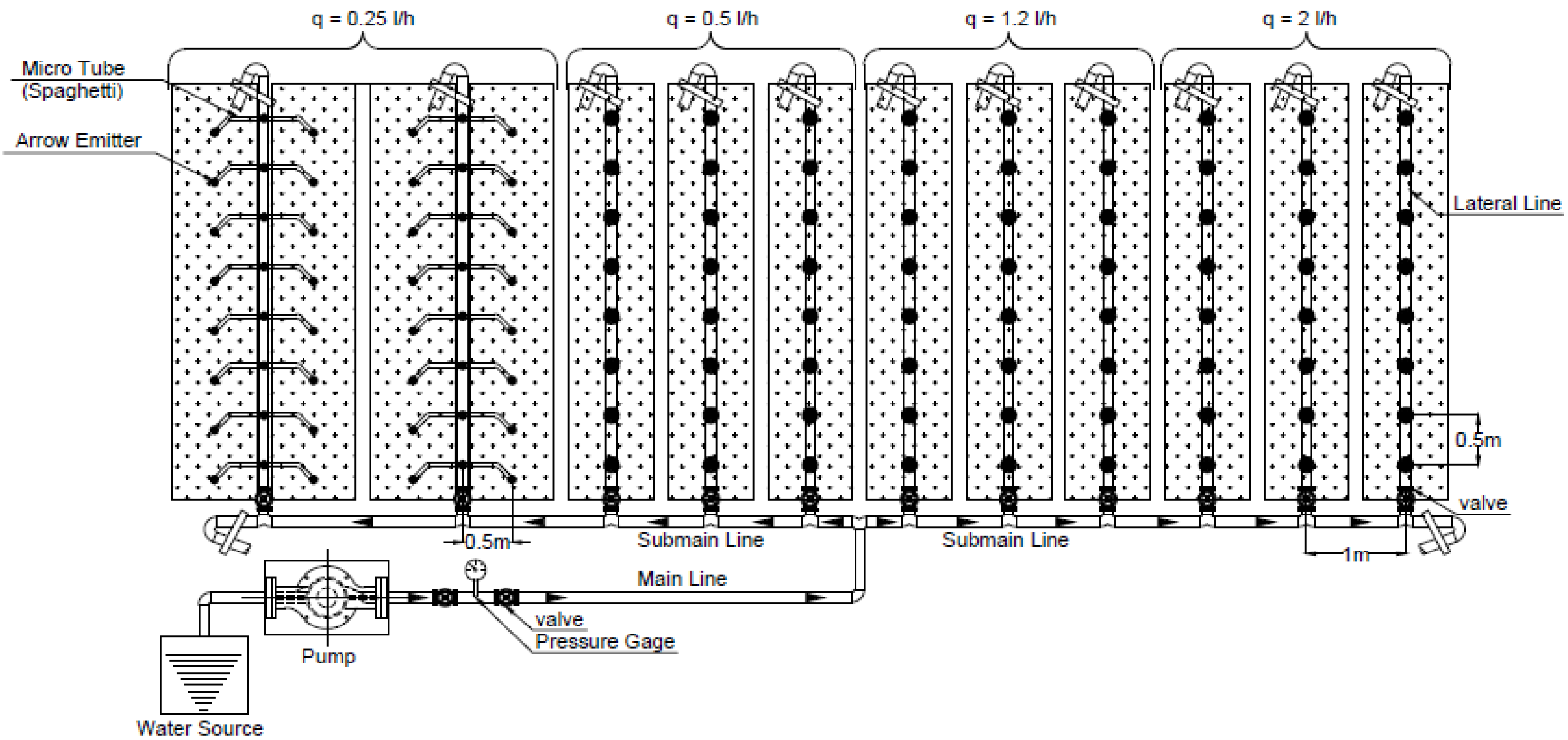


Fig.(2): Schematic sketch of the trickle irrigation system.

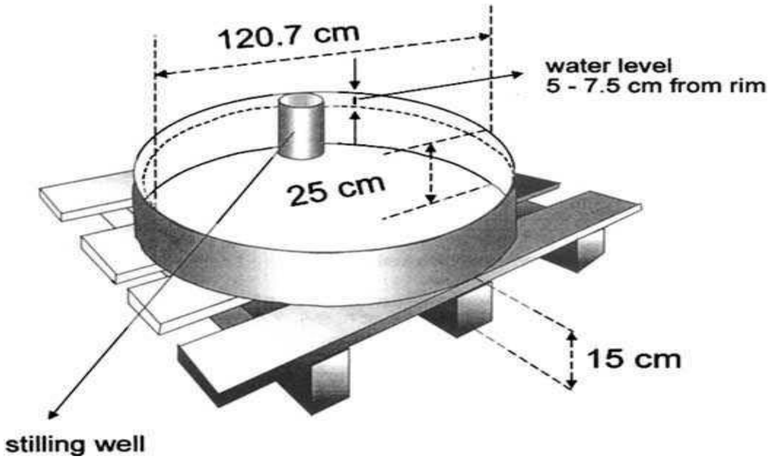


Fig. (3): Class A evaporation pan

Squash (Zucchini) Crop

Table (4): Lengths of crop development stages for various planting periods and climatic regions (days).

Crop	Initial (L_{ini})	Develop (L_{dev})	Mid (L_{mid})	Late (L_{late})	Total Days	Planting Date	Region
Squash, Zucchini	25	35	25	15	100	April; Dec	Mediterranean & Arid

(Source: FAO, 1998a)

Table (5): Single (time-averaged) crop coefficients, K_c,and mean maximum plant heights for non-stressed.**(FAO, 1998a).**

Crop	Kc_{ini}	Kc_{mid}	Kc_{end}	Maximum crop height (h) (m)
Squash, Zucchini	0.5	0.95	0.75	0.3

(Source: FAO, 1998a)

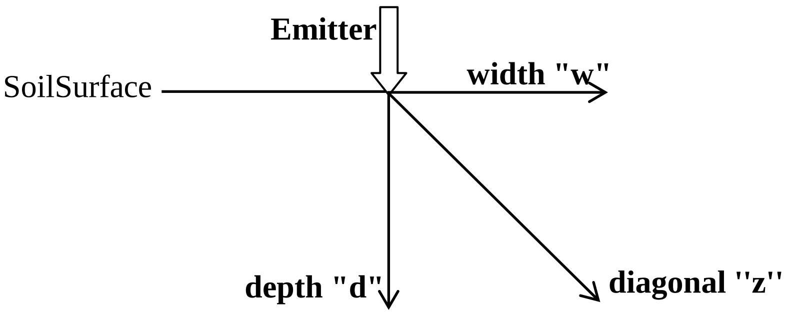


Fig.(4): Directions w, d, and z of wetted front advance in soil under dripper.

The wetted front advance (α) (width "w", depth "d", and diagonal "z") under this method of water application at the end of an irrigation event was assumed to depend on emitter discharge "q", application time "t", and hydraulic conductivity "K" . Therefore, the functional relationships among these parameters may be written as following the methodology applied ley **Awady and Mostafa (1975).**

$$\boldsymbol{\alpha = f\ (q, K, t)} \dots\dots\dots\dots (\mathbf{1})$$

Where:

$\boldsymbol{\alpha}$**:** soil wetted front advance in soil in any direction "w, d, and z" (cm),
$\boldsymbol{f}$**:**constant determined empirically,
$\boldsymbol{q}$ **:** emitter discharge (L/h),
$\boldsymbol{K}$**:** hydraulic conductivity of soil (cm/h), and
$\boldsymbol{t}$ **:**time of application water (h).

By mean of simple dimensional analysis, the variables can be arranged into dimensional analysis groups. A possible form will be,

$$\boldsymbol{\pi_1 = c\ (\pi_2)} \dots\dots\dots\dots (\mathbf{2})$$

$$\boldsymbol{\alpha \left(\frac{K}{q}\right)^{0.5} = c \left(t \frac{K^{1.5}}{q^{0.5}}\right)} \dots\dots\dots\dots (\mathbf{3})$$

In order to determine (c) the laboratory experiments were done.

Determination of water irrigation requirement:

Water Irrigation requirements were calculated by the following equations:

$$\boldsymbol{ET_o = E_{pan} \times K_{pan}} \dots\dots\dots\dots (\mathbf{4})$$

$$\boldsymbol{ET_c = ET_o \times K_c} \dots\dots\dots\dots\dots. (\mathbf{5})$$

$$\boldsymbol{IWR = ET_c \times A \times F} \dots\dots\dots\dots (\mathbf{6})$$

Where:

ET_o**:**potentialevapotranspiration (mm/day),
E_{pan}**:**pan evaporation (mm/day),
K_p **:**pan coefficient "0.55",
ET_c**:**crop evapotranspiration (mm/day),
K_c**:**crop coefficient,
*IWR***:**amounts of applied irrigation water(Lit/Irri.)**,**
*A***:** plant area (m^2), and
*F***:** irrigation frequency (3 days).

Determination of water application time:

The water application time was calculated as in the following equation:

$$I_t = \frac{IWR}{q} \ldots\ldots\ldots\ldots (7)$$

Where:

I_t**:**water application time (h),and

q :emitter discharge (L/h)**.**

RESULTS AND DISCUSSION

Laboratory Experiment

Determination of water distribution:

The main objective of the dimensional analysis is investigational the effect of time of application water "t", hydraulic conductivity of soil "K", and emitter discharge "q" on the water front advance in three directions (w, d, and z). Fig.(5) shows the relation between "π_1" $\{\alpha(K/q)^{0.5}\}$ and "π_2"$\{t(K^{1.5}/q^{0.5})\}$. The relation between (π_1) and (π_2) was fitted as follows:

$$\pi_1 = c\,(\pi_2)^{c1} \ldots\ldots\ldots\ldots (8)$$

The values of parameters "c" and "c_1" depend on (α) direction. By substituting "c" and "c_1" in equation (8). The general expressions for different directions (w, d, and z) were:

$$w = 10.71\ t^{0.47}.K^{0.20}.q^{0.27} \ldots\ldots\ldots\ldots (9)$$

$$d = 15.52\ t^{0.36}.K^{0.04}.q^{0.32} \ldots\ldots\ldots\ldots (10)$$

$$z = 14.04\ t^{0.41}.K^{0.11}.q^{0.30} \ldots\ldots\ldots\ldots (11)$$

Fig.(6)illustrates the relation between w, d, and z observed and w, d, and z calculated by equations (9), (10), and (11). The results showed agreement between those observed and calculated.

Field Experiment

Fig.(7) Shows the relation between growth parameters (plant area "cm^2", plant length "cm", and number of leaves per plant). From it, the greatest of plant area, length, and leaves number were obtained with application rate

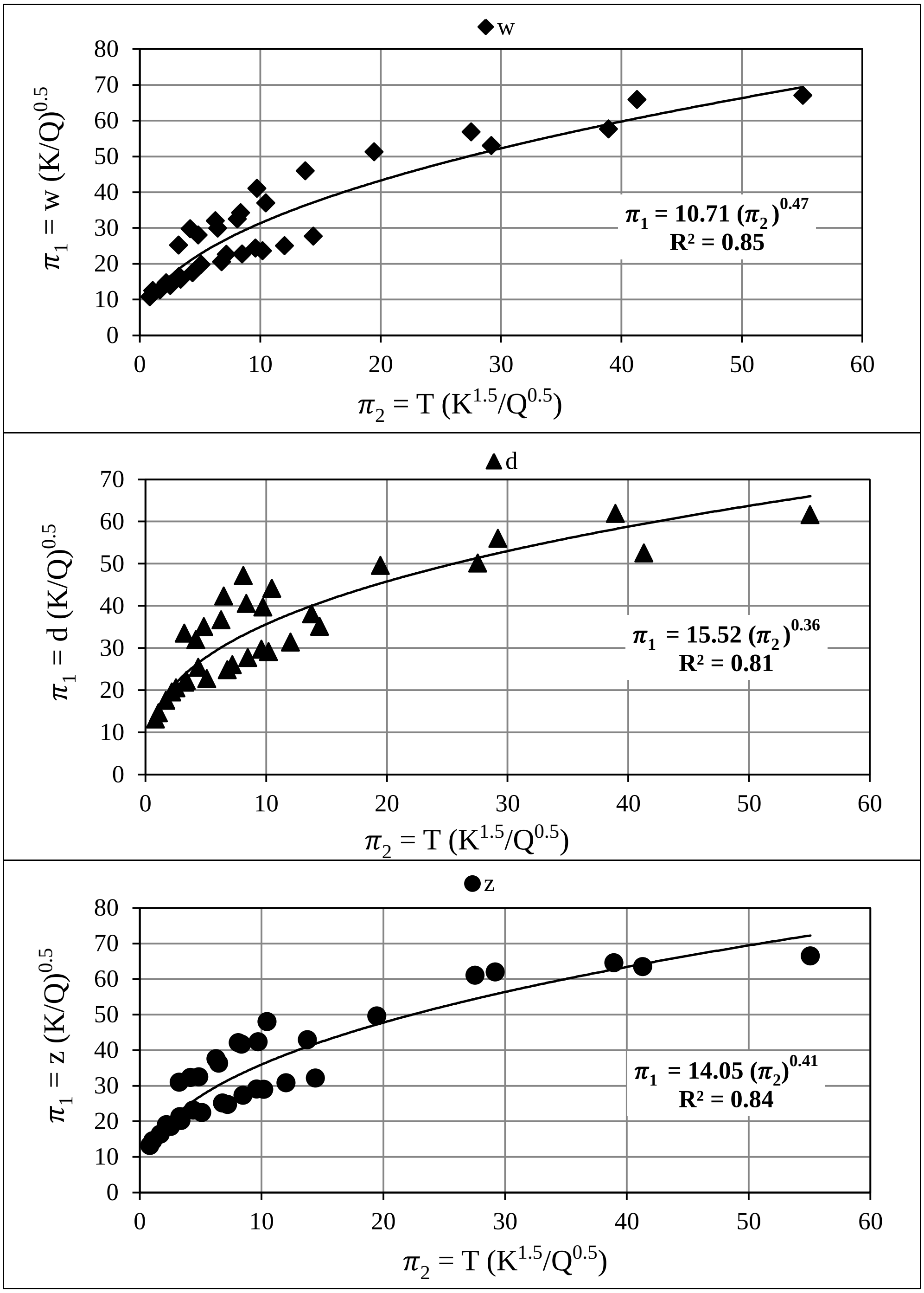
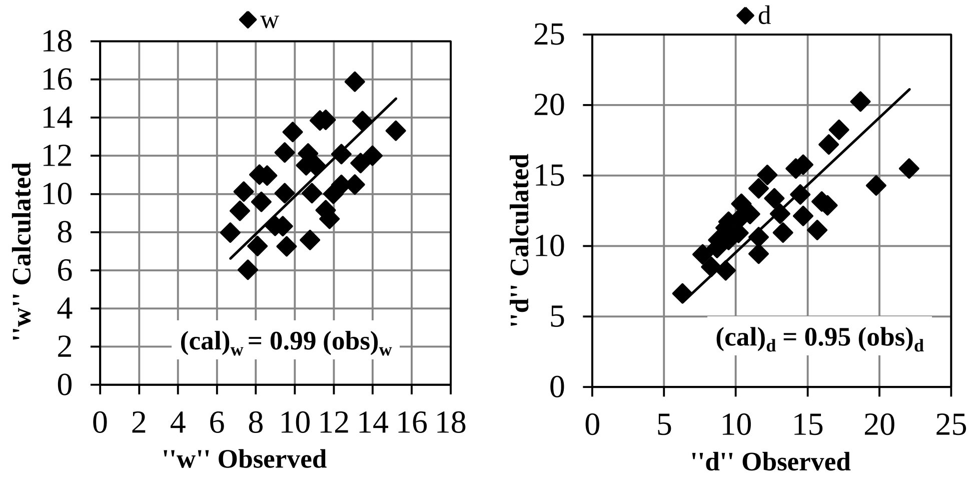


Fig.(5): Relation between various "π_1" and "π_2" terms in the directions (w, d, and z).



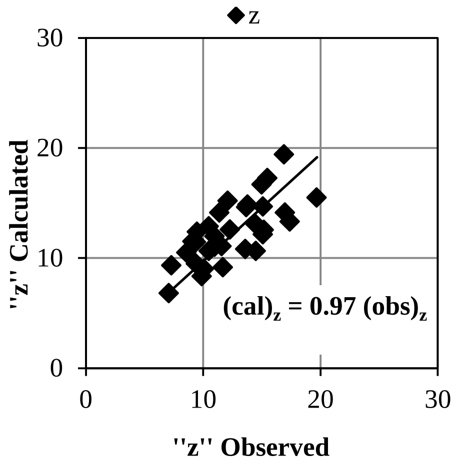


Fig.(6): Relations between soil wetted front advance (w, d, and z) calculated and observed.

0.25 L/h. Also, the increasing ratios of these growth parameters at the end of growing seasonwere 44.17, 53.91, and 37.5% respectively.

Fig.(8) shows squash yield for the four water application rates (0.25, 0.5, 1.2, and 2 L/h). The results indicated that the highest yield was 7.335 kg with application rate 0.25 L/h, and the increasing ratio was 41.17%.

Fig. (9): illustrates the moisture content in soil profile after one hour from irrigation. The results show that the moisture content in the soil below the emitter was unsaturated, but at used emitter with discharge 2 L/h, the moisture content was 14.8 %, its upper field capacity (12.6 %) and using 0.25 L/h discharge rate. The moisture content below the emitter was 12 %, which is lower than field capacity, and the water content at that point decreased with the decreasing the emitter discharge rate. In the wetted pattern below the drip

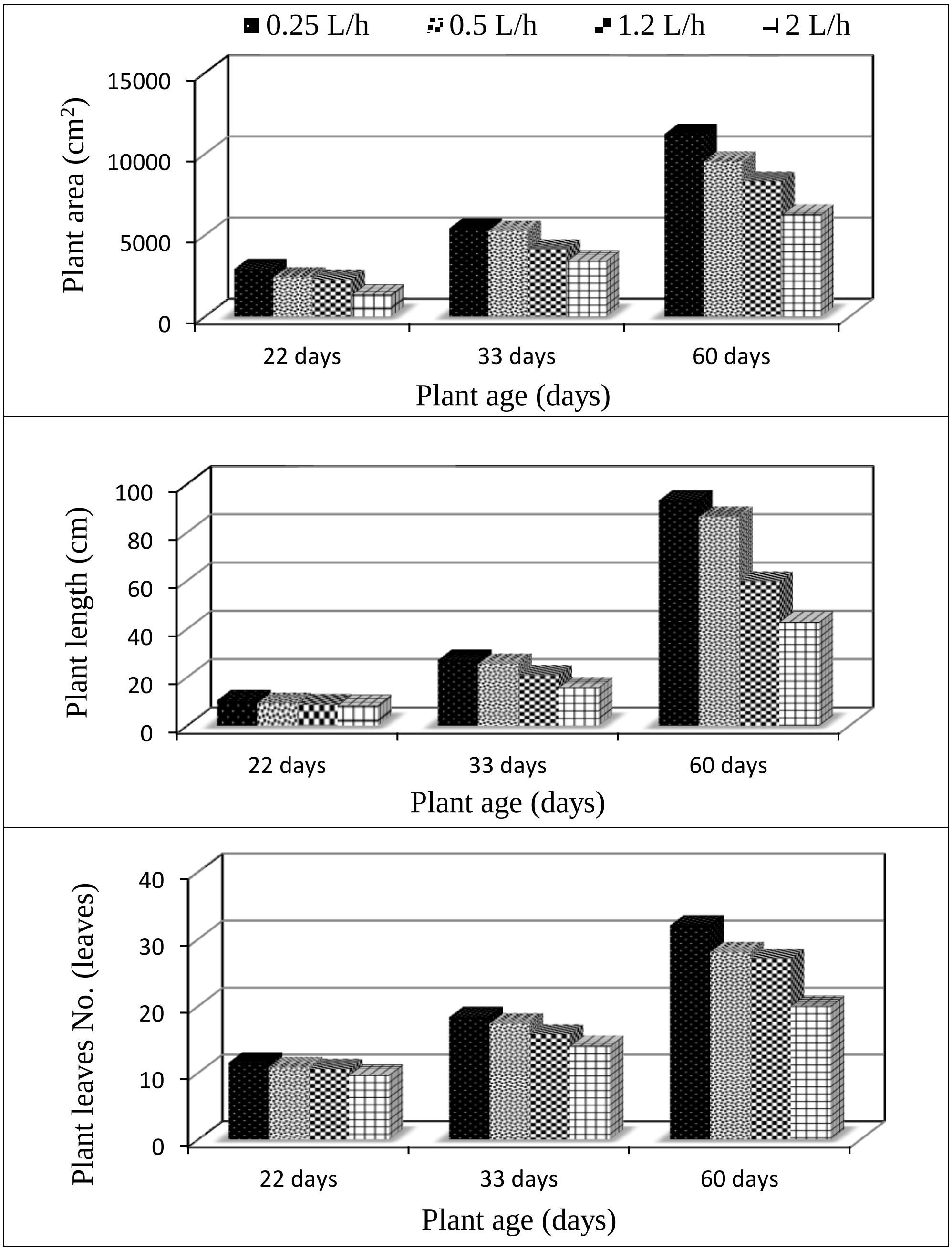


Fig.(7): Relation betweengrowth parameters of plant and plant age "days" at different rates of discharge.

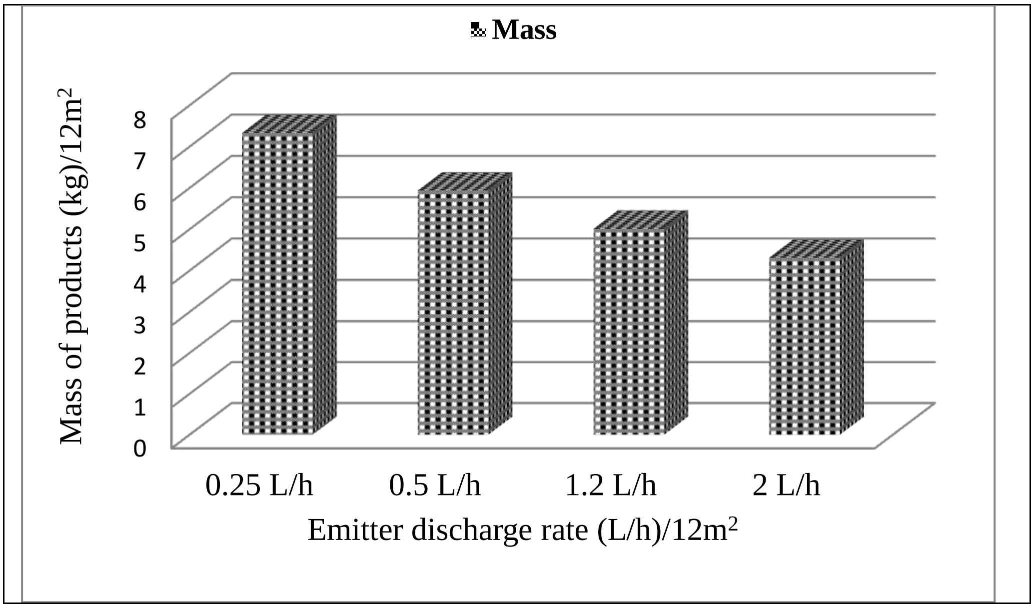


Fig. (8): Relation between squash yield (kg) and four water application rates (0.25, 0.5, 1.2, and2 L/h).

line, extending 20 cm from thehorizontal line and 20 cm in depth. The water content gradient was the steepest with less extreme for 0.25 L/h emitter discharge. The wetted pattern at lower discharge 0.25 L/h was circulas wherethe horizontal wetted front advance was equal to vertical wetted front advance. But at emitter which has discharge of 2 L/h, the wetted shape wasconical where the vertical front advance was larger than the horizontal. These results were obtained using the same volume of water applied.

CONCLUSION

Ultra - low drip irrigation "**ULDI**" is a new aspect of micro irrigation. It is known as "minute or ultra-low flow- rate" irrigation. This method involves applying water at a very low rate. The main objects of this study are :

- Determination of soil wetted pattern using different low discharges with different soils and different application times (**Laboratory Experiment**).
- Effect of Ultra Low Drip Irrigation System on Squash Production(**Field Experiment**).

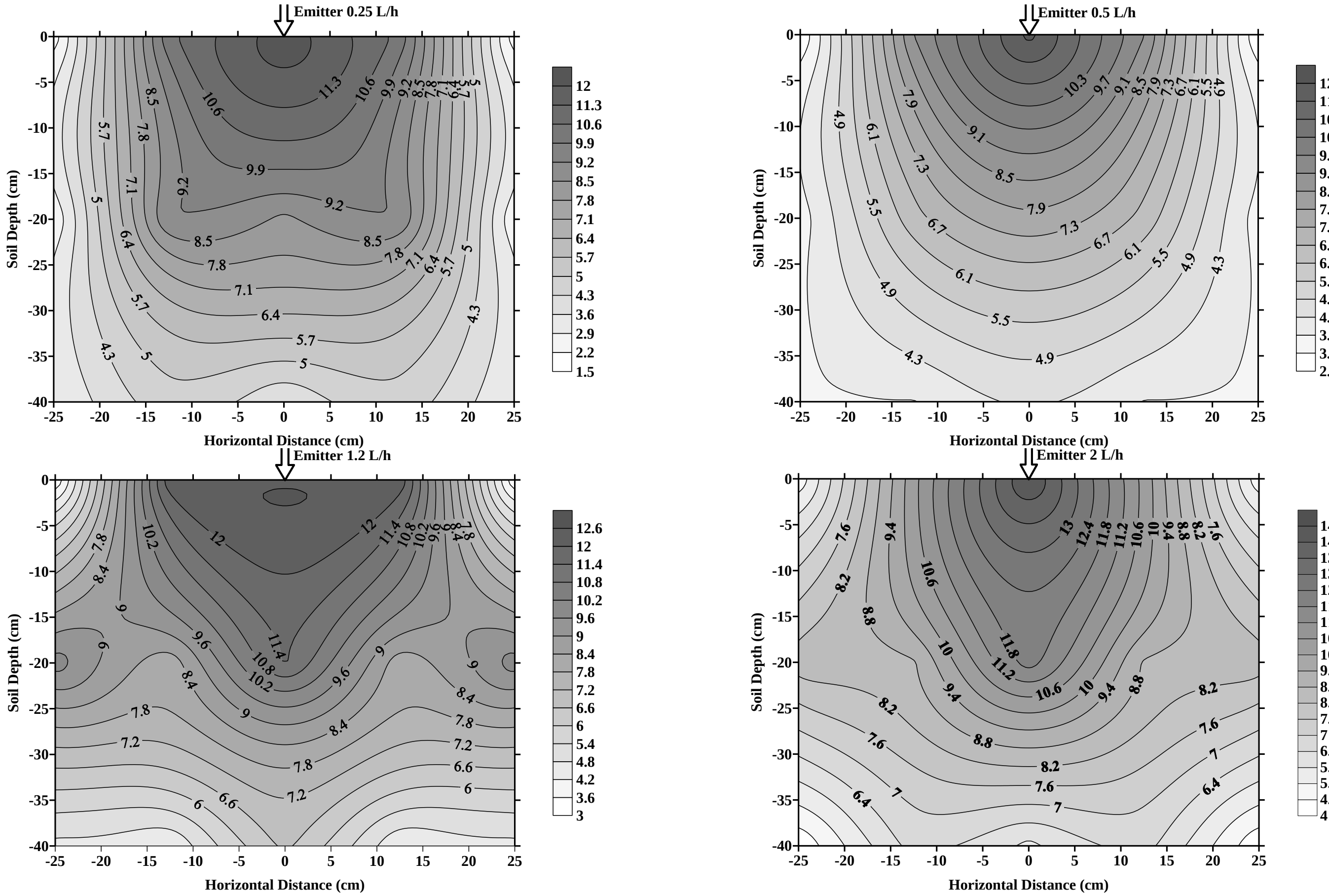


Fig. (9): The moisture content in soil profile after one hour from irrigation as affected by soil depth.

Laboratory Experiment

Wetting patterns are characterized by the horizontal distance of the wetting front "w", the depth of wetting "d", and diagonal distance of wetting front "z" from the point source (emitter).(α) in three directions was determined by dimensional analysis.The results gave the following equation:

$$\alpha = c\ .t^{c_1}.K^{c_2}.q^{c_3}$$

where(α) is in any direction (w, d, or z),**c**, $\mathbf{c_1}$, $\mathbf{c_2}$, and $\mathbf{c_3}$are constants depending on (α) direction.This equation is in agreement with the results of **Awady andMostafa; (1975) and Elmesery (2011).**

Field Experiment

A somewhat higher yield was obtained for the 0.25 L/h and 0.5 L/h discharges.The increasing ratios of yield were 41.17 % and 27.36 %, respectively. This is in agreement with the results of **Assouline et al. (2002)**.

The moisture content in soil profile under emitter point was around field capacities of (12%, 12.1%, 12.6%, and 14.8%) at application rates 0.25, 0.5, 1.2, and 2 L/h respectively. The wetted pattern at lower discharge 0.25 L/h was circular where horizontal wetted front advance was equal to vertical wetted front advance. But at emitter which has discharge 2 L/h, the wetted shape was conical where vertical front advance was larger than horizontal.

REFERENCES

Assouline, S., S. Cohen, D. Meerbach, T. Harodi, and M. Rosner.(2002). Microdrip irrigation of field crops: Effect on yield, water uptake, and drainage in sweet corn. Soil Sci. Soc. Am. J. 66:228–235.

Aragues, R., E. Playan, R. Ortiz and A. Royo, 1999.A new drip-injection irrigation system (DIS) for cropsalt tolerance evaluation. Soil Sci. Soc. Am. J,. 63: 1397-1404.

Awady, M. N. and Mostafa, M., (1975). Infiltration of water from tricklers into loamy soils, Egypt J. Soil Sci, Special Issue, :p. 209 – 214.

Elmesery, A. A. M., (2011). Water movement in soil under micro trickle irrigation system. Misr.J. Agr. Eng. Vol. 28(3), :p. 612-629.

FAO (1998). Crop evapotranspiration – Guidelines for computing crop water requirements.

Koenig, E. (1997). Methods of micro-irrigation with very small discharges and particularly low application rates(In Hebrew.).WaterIrrig. 365:32–38, (cited fromAssouline, 2002 and Badr, 2007).

Lubars, P. and Richard, M., (2008).

http://www.scribd.com/doc/8145273/p13

Sne, M., (2009). Micro Irrigation Technology and Application.Second version, Shirley Oren, Publications' Coordinator, CINADCO.

الملخص العربى

تأثير الرى بالتنقيط المتناهى الدقة على توزيع الرطوبة فى التربة وإنتاجية الكوسة

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يعتبر نظام الرى بالتنقيط المتناهى الدقة من أنظمة رى الميكرو (Micro Irrigation) الحديثة ويتميز هذا النظام بإضافة معدلات مياه منخفضة جداً أقل من معدل امتصاص التربة للمياه حيث أن تصرفهيتراوح بين ٠,٢ – ٠,٥ لتر/ساعة. ويفضل هذا النظام لأسباب عديدة منها طول فترة إضافة المياه بمعدلات قليلة وزيادة نسبة الأكسجين فى التربة.**و يهدف هذا البحث إلى:**

- دراسة شكل البلل فى أنواع مختلفة من التربة تحت هذا النظام.
- دراسة تأثير هذا النظام على نمو وإنتاجية نبات الكوسة.

متغيرات الدراسة:

أولاً: التجربة المعملية

- تم استخدام نوعين من التربة أحدهما رملية والأخرى طينية بعد تجفيفهما هوائياً.
- تم استخدام أربع معدلات تصرف مختلفة هى ٠,٢٥ و ٠,٥ و ١,٢ و٢ لتر/ساعة - وتم الحصول على هذه التصرفات من خلال نقاطات حديثة (PCJ On Line Dripper) ، مع أربع أزمنة إضافة مختلفة لكل تصرف.

ثانياً: التجربة الحقلية

- تم زراعة نبات الكوسة فى الفترة من ٣٠ / ٥ / ٢٠١١م إلى ٨ / ٨ / ٢٠١١م تحت نظام الرى بالتنقيط الدقيق بأربع معدلات تصرف مختلفة(سابقة الذكر).
- تم تصنيع وعاء بخر(Evaporation Pan) لتحديد الإستهلاك المائى (ET_o)مع الإستعانة بجداول الـ FAO فى تحديد قيمة معامل المحصول K_c.

القياسات:

أولاً: التجربة المعملية

- تم قياس مسافة البلل عند أزمنة مختلفة فى ثلاث اتجاهات (الأفقى والرأسى والقطرى) فى نوعى التربة لكل تصرف.
- تم قياس المحتوى الرطوبى فى قطاع البلل.

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ثانياً: التجربة الحقلية

- تم قياس المحتوى الرطوبى فى قطاع التربة أفقياً على أبعاد صفر و ١٢,٥ و٢٥ و ٣٧,٥ و ٥٠ سم من النقاط – ورأسياً على أبعاد صفر و ٢٠ و ٤٠ سم من سطح التربة.
- تم قياس بعض الصفات الخضرية للنبات هى طول النبات وعدد أوراق النبات ومساحة ظل النبات فى مراحل نموه المختلفة وأيضاً تم قياس الإنتاجية.

النتائج:

أولاً: النتائج المعملية :

باستخدام طريقة التحليل البعدى تم الحصول على المعادلة الآتية :

$$\alpha = c \, . \, t^{c_1} . \, K^{c_2} . \, q^{c_3}$$

حيث:

α : اتجاه البلل (إما أفقى، رأسى، أو قطرى) (سم)

t : زمن إضافة المياه (ساعة)

K : التوصيل الهيدروليكى للتربة (سم/ساعة)

q : معدل تصرف النقاط (لتر/ساعة)

$c, c_1, c_2,$ and c_3 : ثوابت تتوقف على الإتجاه ونوع التربة.

ثانياً: النتائج الحقلية :

- المحتوى الرطوبى حول منطقة الجذور كان دائماً يقترب من السعة الحقلية حيث كان يساوى ١٢ و ١٢,١ و ١٢,٦ و ١٤,٨% عند استخدام معدلات إضافة ٠,٢٥ و ٠,٥ و ١,٢ و ٢ لتر/ساعة على الترتيب - وذلك يهيئ بيئة مثلى لنمو الجذور من حيث توازن الماء والهواء فى التربة.
- التبكير فى الإنتاجية كان تحت معاملتى ٠,٢٥ و ٠,٥ لتر / ساعة وكانت نسبة الزيادة فى الإنتاج لمعاملة ٠,٢٥ لتر/ساعة ٤١,١٧% ونسبة الزيادة لمعاملة ٠,٥ لتر/ساعة كانت ٢٧,٣٦%.