J. Agric. Sci. Mansoura Univ., 32 (8): 7023 - 7035, 2007

IMPACT OF MICROIRRIGATION APPLICATION REGIMES ON MOISTURE, SALINITY AND PHOSPHORUS DISTRIBUTION IN SOIL

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ABSTRACT

A Field experiment was conducted in newly reclaimed desert soil to study the effect of three different application regimes of microirrigation system on the distribution of soil moisture, salinity and available–P in the soil.

Irrigation water application regimes through microirrigation (drip irrigation) system were applied in three different treatments (Continuous and two different intermittent applications). An equal volume of applied water (4 l/h) was delivered to each treatment daily. Phosphorus as phosphoric acid was applied to each treatment with irrigation water at rate of 45 mg P /l. A grid system 10 x 20 cm covering three adjacent emitters for each treatment were chosen to collect the surface soil samples (0-20 cm) from the crossing points for determining soil moisture, salinity and available–P.

The results revealed that soil moisture distribution within certain distance from emitter and the wetted radius under continuous application is higher than that under intermittent applications. Soil salinity decreased under continuous application rather than under the intermittent application. Available P concentrations in the soil surrounding the emitter were found to be higher in continuous application as compared with intermittent irrigation regimes.

The relationships between soil moisture and soil salinity were described by power decrease equations whereas the soil moisture impact on available-P could be represented by power increase equations.

Keywords: Microirrigation, soil moisture, salinity, available-P, continuous, intermittent

INTRODUCTION

Microirrigation is defined as the frequent application of small quantities of water directly above the soil surface; usually as discrete drops, continuous drops, tiny streams, or microscopy; through emitters or applicators placed along a water delivery. Microirrigation encompasses a number of methods or concept; such as drip, subsurface, bubbler and microscopy irrigation (Batchelor et al., 1996).

Fertilizers applied through the micro-system are more efficiently used by plants because only a small amount is maintained in the soil at a time; thus leaching and run-off are minimized throughout the growing season. Applied in proper amounts, injected fertilizers also are less likely than soil-applied dry fertilizers to injure the plant's root system from salt damage, since the liquid fertilizer is highly diluted in the irrigation water. Fertigation provides another significant benefit in making fertilizer application possible at any time (Bar-Yosef, 1999)

Drip (trickle) irrigation has been shown in a number of studies to be particularly effective in increasing efficiency of P fertilization. Whether the P is applied through the irrigation system or simply made more available through maintenance of high water contents, P concentrations in solution are increased, resulting in increased P mobility to roots (Mikkelsen, 1989; Rubiez et al., 1991).

An important result of using drip irrigation systems for P application is that less P fertilizer is generally required to achieve sufficient plant P concentrations compared with other application methods (Bacon and Davey, 1982; Mikkelsen, 1989; Rubiez et al., 1991). Such studies support the hypothesis that continuous P applications in drip irrigation systems will further increase P availability.

Kargbo et al. (1991) hypothesized that diffusion directly to the root limits P uptake. They discovered, however, that increasing P application frequency resulted in greater P uptake and suggested that the higher P application frequency caused greater mass flow and greater mixing action, leading to the breakdown of regions of immobile P.

This research was carried out to study the effect of three different application regimes of microirrigation system on the distribution of soil moisture, salinity and available–P in newly reclaimed desert soil of Egypt.

MATERIALS AND METHODS

A field experiment (May 2006) was conducted in newly reclaimed desert soil, located at (E 30 02' 15"; N 30 44' 15") about 135 km north Cairo Alex desert Road. The area was previously cultivated with vegetable cash crops. Chemical and physical properties of the soil were determined according to Page et al. 1982, and presented in Tables 1 and 2. Irrigation water was drawn from local canal which is a branch of El Nasr main canal for such location, the chemical analysis of irrigation water is introduced in Table 2.

Table 1: Some physical and chemical properties of the soil.

C. Sand %	F. Sand %	Silt %	Clay %	Texture class	$CaCO_3$ %	O.M %	CEC $Cmol_c kg^{-1}$
39.2	28.4	19.1	13.3	Loamy Sand	6.6	0.7	18.2

Table 2: Chemical analysis of 1:1 soil extract and water sample.

Samples	pH	EC dSm^{-1}	Soluble anions (meq l^{-1})			Soluble cations (meq l^{-1})			
			HCO3	Cl	SO4	Na	K	Ca	Mg
Soil	7.8	2.34	2.2	14.8	7.6	12.3	0.3	5.8	6.2
Water	7.4	0.63	1.4	2.2	2.8	3.2	0.1	1.8	1.3

Experiments

1- Phosphate sorption isotherm

The P sorption isotherm was conducted by adding 2 g of air dried soil (< 2 mm) in 50 ml shacking tube with 20 ml of solution containing various concentrations of 2.5, 5, 10, 20, 30, 40 and 50 mg P/l. The tubes were mechanically shaken for 24 hours. The soil suspensions were centrifuged for 15 min and filtered through a 0.45µm membrane filter. Each P level was determined in triplicate according to Page et al. (1982). The adsorbed amounts of P were calculated from the difference between initial and final concentration. The data were fit to a Langmuir sorption isotherm and are shown in Fig. 1.

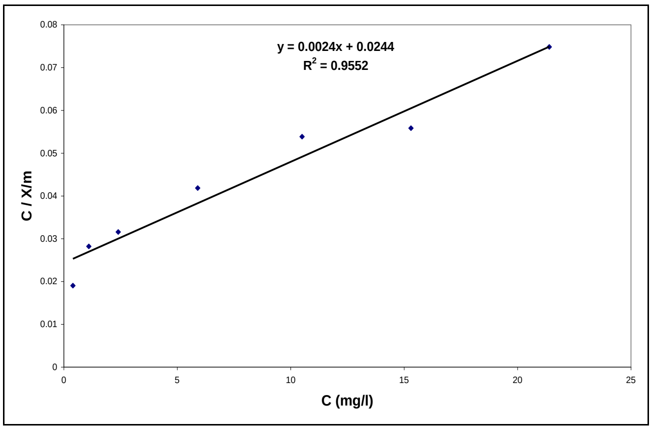

Fig. 1: Langmuir plot of P adsorption.

2- Irrigation application

Raised beds of width 80 cm and length of 32 m were prepared, and the laterals were put on these beds. Distance between emitter was 0.5 m and distance between lateral was 1 m apart. Irrigation water application regimes through microirrigation (drip irrigation) system were applied in three different treatments, T1 application of irrigation water for 60 minutes continuously, T2 application of irrigation water for 30 minutes and shut down for 2 hours and then operating for 30 minutes and T3 application of irrigation water for 15 minutes and shut down for 2 hours then repeated four times. An equal volume of applied water (4 l/h) was delivered to each treatment daily. Phosphorus was applied to each treatment with equal concentration in irrigation water of 45 mg P /l (15 kg P /fed) from phosphoric acid (in 20 application dosages divided into two application times per week for 10 weeks).

A grid system 10 x 20cm covering three adjacent emitters for each treatment was chosen to collect the soil samples from the crossing points of the grid. Moisture, salinity (1:1 extract) and available phosphorus were determined in the collected soil samples at the end of the experiment duration (Page et al, 1982).

Specifications of the microirrigation system used

GR Emitters with flow rate 4 l/h at operating pressure of 1 bar were utilized. Venturi injector was used to inject the diluted phosphoric acid from an open plastic tank of 80 l, while the diluted water contained 800 g of phosphoric acid in final volume of 50 l water in the tank. Specifications for the venturi injector used in this experiment were introduced in Table 3.

Table 3: Specifications for the venturi injector

venturi	measure	unit
diameter	1	inch
flow velocity	1.5	m/sec
flow rate	1.852	m3/h
pressure before venturi	2.2	
pressure after venturi	1.8	
pressure drop	0.4	bar
pressure drop ratio	18.18	%
suction flow rate	90	L/h
suction flow rate	1.5	L/min

RESULTS AND DISCUSSION

Phosphate adsorption isotherm

The Langmuir adsorption isotherm (Fig. 1) shows that the soil has a capacity for adsorbing P. Moreover, the adsorption isotherm indicates that saturation of the P sorption sites was unlikely to have occurred under experimental conditions since the solution P and adsorbed (bicarbonate extract-able) P concentrations were within the range of the data in Fig. 1.

Soil moisture distribution

Fig. 2 depicts the moisture distribution for the three treatments, in both directions, parallels to the lateral line (x-axes) and in the perpendicular direction (y- axes).Under treatment-T1, it can be seen (Fig 2), that soil moisture reaches the highest value (>24% v) close to the emitter with wetted radius is about 7 to 12 cm and 3 to 5 cm for (x-axes) and (y- axes), respectively. As distance increase from the emitter, the soil moisture value reaches (20-24% v), with wetted radius is about 15 to 22 cm and 7 to 10 cm for (x-axes) and (y- axes), respectively. Overlapping of soil moisture value (16- 20% v) was observed around the three emitters for (x-axes).Whereas, it reaches 15-20 cm for (y- axes). Soil moisture reaches the lowest value (4-8% v), which affected by the wetted zone, far from emitter, the wetted radius is about 40 cm for (y- axes).

Regarding treatment T2, (Fig 2), soil moisture reaches the highest value (>18% v) close to the emitter, with wetted radius is about 0 to 8 cm and 0 to 5 cm for (x-axes) and (y- axes), respectively. As distance increase from the emitter, soil moisture value reaches (15-18 % v), with wetted radius is about 7 to 12 cm and 5 to 8 cm for (x-axes) and (y- axes), respectively. Two overlapping mid points were observed for x-axes, the first one 6-9 %v, while the second one is 3-6 % v. Soil moisture reaches the lowest value (3-6 % v), which affected by the wetted zone, far from emitter, with wetted radius is about >35 cm for (y- axes).

The results of treatment T3, introduced in (Fig 2), revealed that soil moisture value 12-14 %v close to the emitter, with wetted radius is about 6 to 11 cm and 2 to 6 cm for (x-axes) and (y- axes), respectively. Two overlapping mid points were observed for x-axes, the first one 6-8 %v while, the second one is 4-6 %v.

The wetting patterns during application generally consist of two zones: (i) a saturated zone close to the emitter, and (ii) a zone where the water content decreases toward the wetting front. In general, it can be concluded that soil moisture distribution under the emitters within any certain distance could be arranged in descending order as following: T1 > T2 > T3. This finding indicates that the wetted radius increased with increasing continuous application operating time of irrigation. This result is in a good agreement with (Ah Koon et al., 1990 and Kramer et al., 2001).

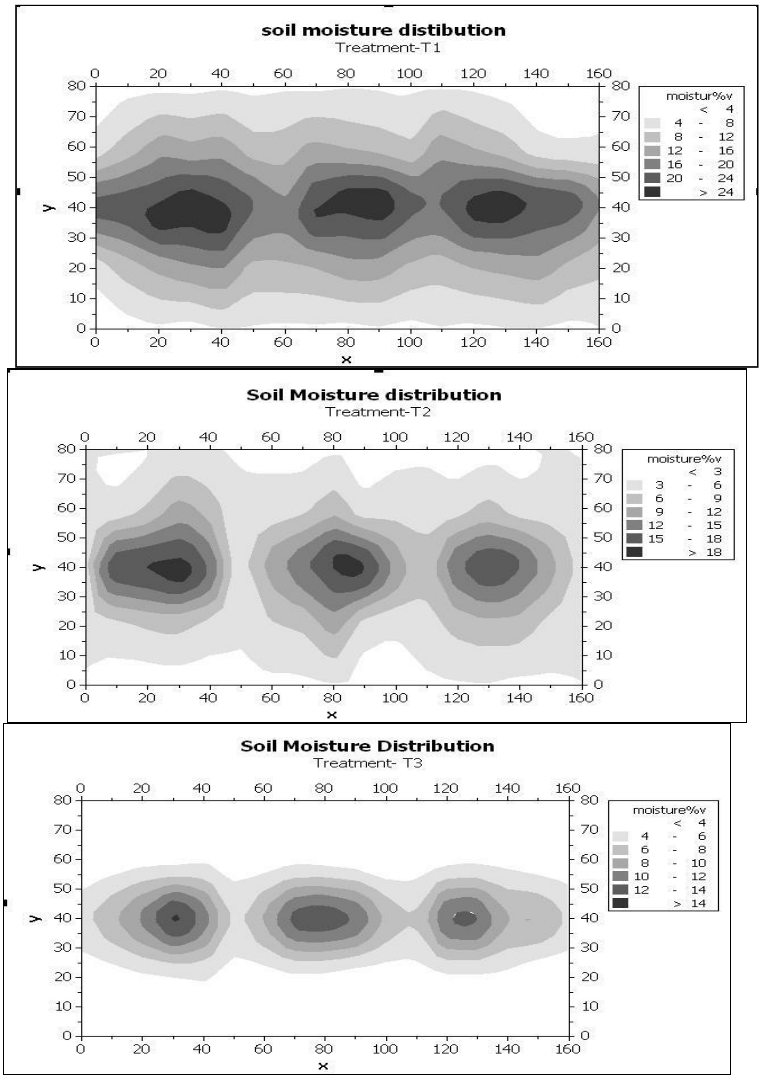

Fig. 2: Soil moisture distribution pattern under different three treatments.

Soil salinity Distribution

The drawback effect of microirrigation is so called secondary salinization, which is caused by an accumulation of salts at the edges of the wetting front far from emitters. In areas such as Egyptian deserts where the climate is hot and dry region, irrigated soils with such system are subject to substantial water losses through evapotranspiration. Salts contained in irrigation water remain in the soil and increase in concentration when the water evaporates from the soil

Figure 3 shows that the soil salinity values varied in a wide range. Concerning EC(1:1), it was found that its values increased from (<0.26 to >8.3), (<0.41 to >8.3) and (2.0 to <8.0) dS/m for T1, T2 and T3, respectively. Soil salinity under emitter showed little differences between T1 and T2 while there is a significant difference between previous treatments and T3 as EC(1:1) values are (<0.26), (<0.41) and (2.0) dS/m for T1, T2 and T3, respectively. Overlapping of soil salinity values (0.26 - 1.86), (1.98 - 3.56) and (2.00 – 4.00) dS/m were observed around the three emitters for (x-axes) for T1, T2 and T3, respectively.

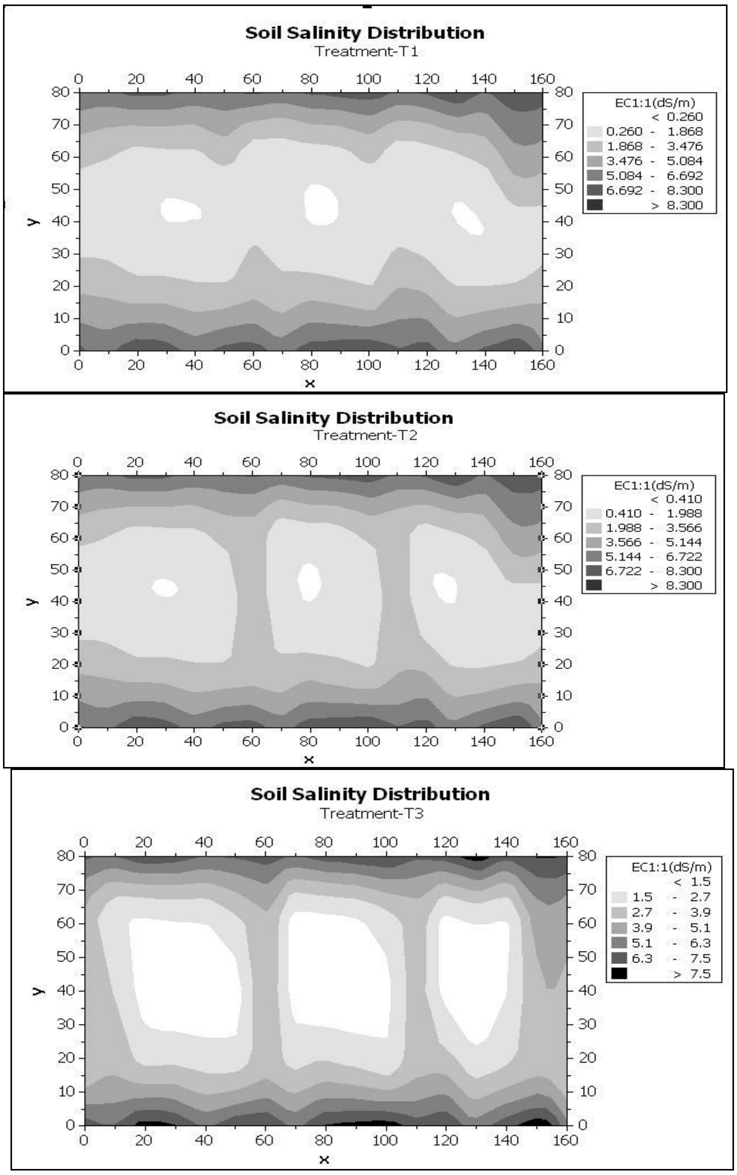

Fig. 3: Soil salinity distribution pattern under different three treatments

In general the soil salinity decreased with continuous application irrigation rather than under the intermittent applications. Therefore to avoid soil salinization under microirrigation, continuous irrigation has to be applied to the field in order to leach the salt far from the emitter. This result is in a harmony with the result of Assouline et al., 2006**.**

Phosphorus Distribution

Figure 4 reveals that when drying and wetting occurs as in the treatments T2 and T3, available-P concentrations were less than those existed under the continuous application (T1). Available-P concentrations in the soil immediately surrounding the emitter were found to be 12.5 to 16.5% higher in continuously irrigated soil as compared with intermittent irrigation regime. In the continuous treatment (T1), an area of relatively high P concentration was maintained along both directions (x-axes and y-axes), with maximum P reached nearly >20 mg kg^{-1}. Distance of P movement was 2-4 cm and 2-5 cm for (x-axes) and (y- axes), respectively. With increasing distance from emitter, P concentration value was (11-14 mg kg^{-1}), with radius of about 10 to 22 cm and 15 to 20 cm for (x-axes) and (y- axes), respectively. Overlapping zone of P concentration value (8-11 mg kg^{-1}) for (x-axes) was observed around the three emitters, whereas it reaches 22-30 cm for (y- axes). Available P concentrations quickly diminished, and ended with minimum levels of 5-8 mg kg^{-1} of about 31-37 cm for (y-axes).

Available-P concentrations under treatment T2 were characterized by sudden decreasing in a large portion of the soil surface immediately around the emitter and then gradual, mostly with the movement of the water. Available P concentration value was (15-17.5 mg kg^{-1}) around the emitter, to the radius of about 3-8 cm and 3-6 cm for (x-axes) and (y- axes), respectively. Overlapping zone of P concentration value (7.5-10 mg kg^{-1}) for (x-axes) was observed around the three emitters, whereas it reaches 25 cm for (y- axes). Available P concentrations quickly diminished, and ended with minimum levels of 5-7.5 mg kg^{-1} of about 20 to 37 cm for (y-axes).

Despite the close similarity of available-P concentration distributing under treatment T2 and T3, there was a little lateral spread of P on the surface of the soil with T3 irrigation regime. Available P concentration value was (14-16.5 mg kg^{-1}) around the emitter, to the radius of about 2 to 6 cm and 3-5 cm for (x-axes) and (y- axes), respectively. Overlapping zone of P concentration value (4-6.5 mg kg^{-1}) for (x-axes) was observed around the three emitters, whereas it reaches 30 cm for (y- axes), and ended with this level.

In general, it can be concluded that available-P concentration distribution under the emitters within any certain distance could be arranged in descending order as following: T1 > T2 > T3. This finding indicates that the P movement decreased with increasing distance from emitter and however, it increased with increasing soil moisture content. Several studies of P transport suggest that maintenance of relatively high moisture under microirrigation lead to greater P mobility and availability (Mbagwu and Osuigwe, 1985; Bar-Yosef et al., 1989; Kargbo et al., 1991).

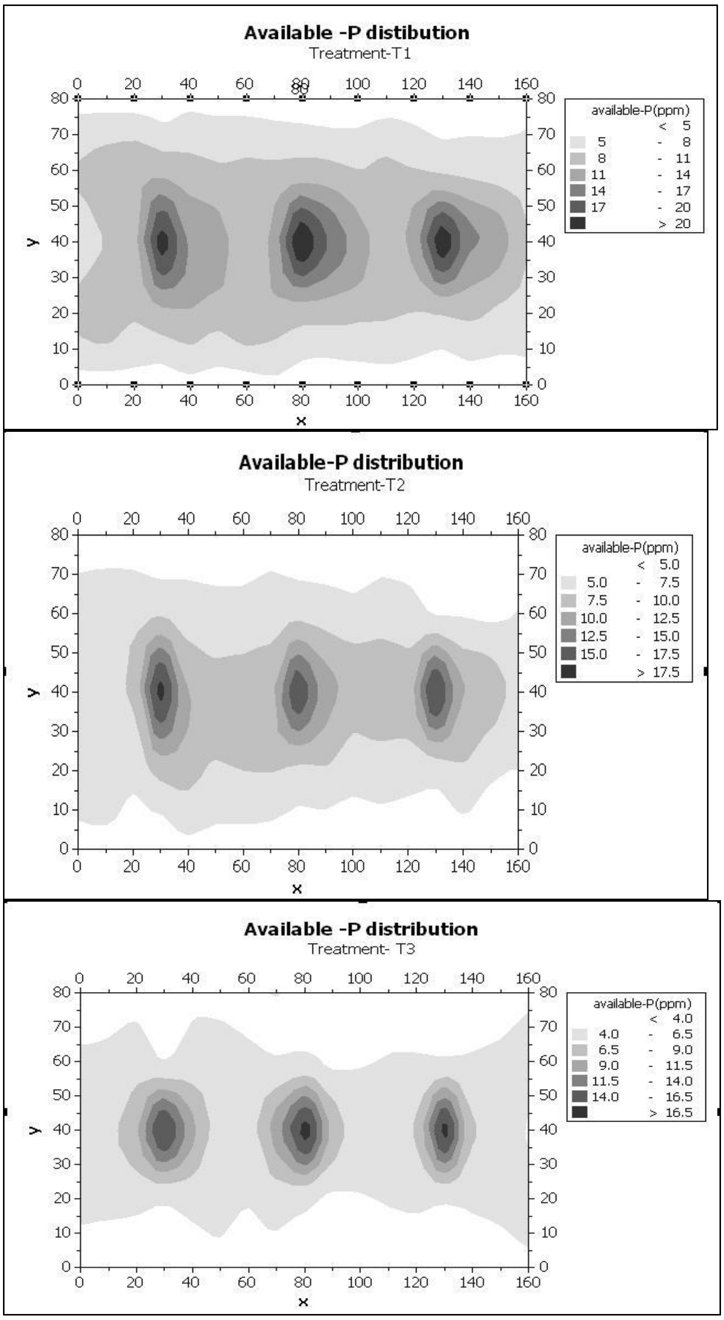

Fig. 4: Available-P distribution pattern under different three treatments.

Relationship between soil moisture %v and soil salinity (EC1:1 dS/m)

Figure 5, shows that the soil salinity of the three treatments decreased with increasing in soil moisture contents. Sharp decrease was observed in the values of soil salinity till soil moisture value of 10, 6 and 4 %v, then little decline was found from soil moisture content (10 to 25), (6-19) and (4-13) %v for T1, T2 and T3, respectively.

Regarding the results of the three treatments, power decrease equations were derived, as following:

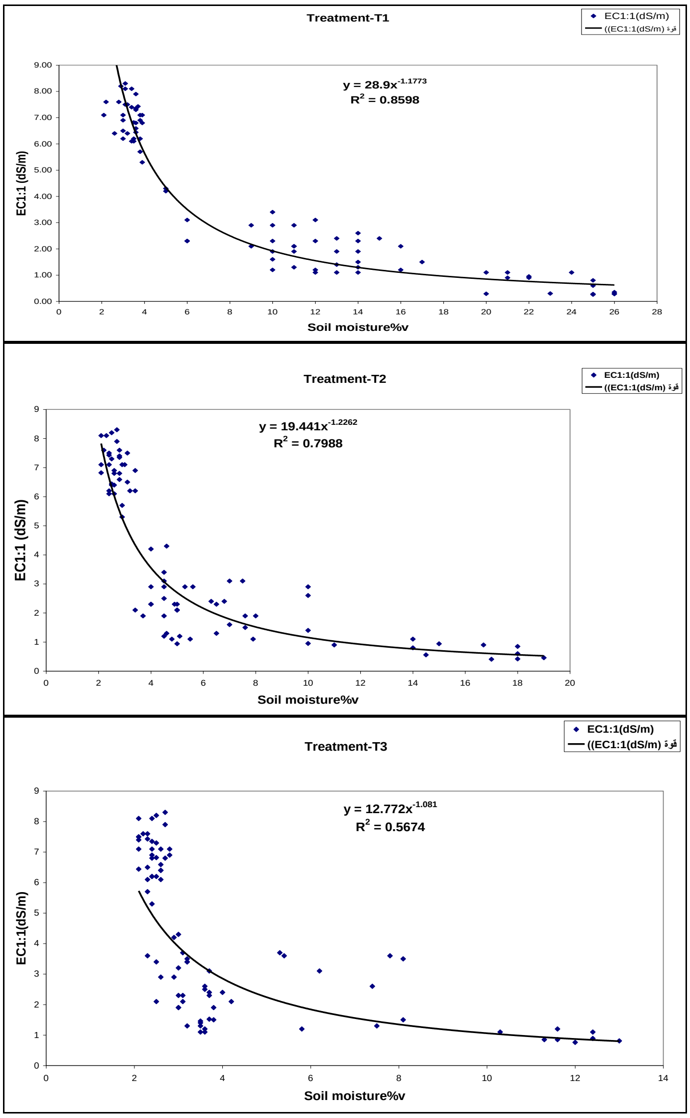

Fig. 5: Soil moisture vs EC 1:1.

for T1 $Y = 28.900 \; X^{-1.177}$, $R^2 = 0.859$
for T2 $Y = 19.441 \; X^{-1.226}$, $R^2 = 0.798$
for T3 $Y = 12.772 \; X^{-1.081}$, $R^2 = 0.798$
where Y is the EC1:1 (dS/m), X soil moisture %v, R^2 coefficient of determination.

Relationship between soil moisture %v and Available-P

Figure 6 shows that the available-P concentrations of the three treatments have clear increment with increasing soil moisture contents. Maximum available–P values were 22, 18 and 17.5 mg/kg which occurred at soil moisture levels of 26, 19 and 13 %v for T1, T2 and T3, respectively.

Regarding the results of the three treatments, power increase equations were derived, as following:

for T1 $Y = 1.5624 \; X^{0.6849}$, $R^2 = 0.880$
for T2 $Y = 1.9544 \; X^{0.6409}$, $R^2 = 0.794$
for T3 $Y = 1.9339 \; X^{0.6358}$, $R^2 = 0.762$
where Y is available–P(mg/kg), X soil moisture %v and R^2 coefficient of determination.

Utilizing the equations previously described, with hypothetical values for soil moisture and the resulted values for available P (mg/kg) are presented in Fig.7. Despite phosphorus transport by diffusion, as sorption and precipitation are dominant in determining P mobility, Fig.7 reveals that convection can play an important role of P movement under certain levels of soil moisture conditions. The extent of P movement, according to Mikkelsen (1989), is dependent on the saturation of soil reaction sites. While P is applied to a limited soil volume near the emitter, it will continue to move with the irrigation water at some rate, depending on the particular soil characteristics. If the drying process is reduced or avoided through high-frequency irrigation, P remains in soil solution and is transported farther into the wetted zone.

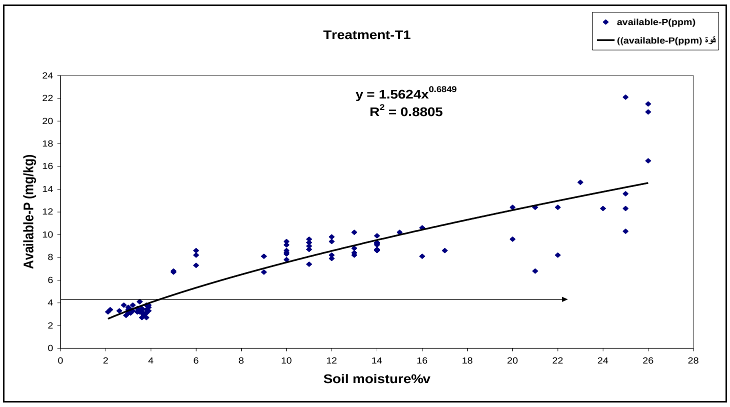

Fig. 6: Soil moisture vs available-P.

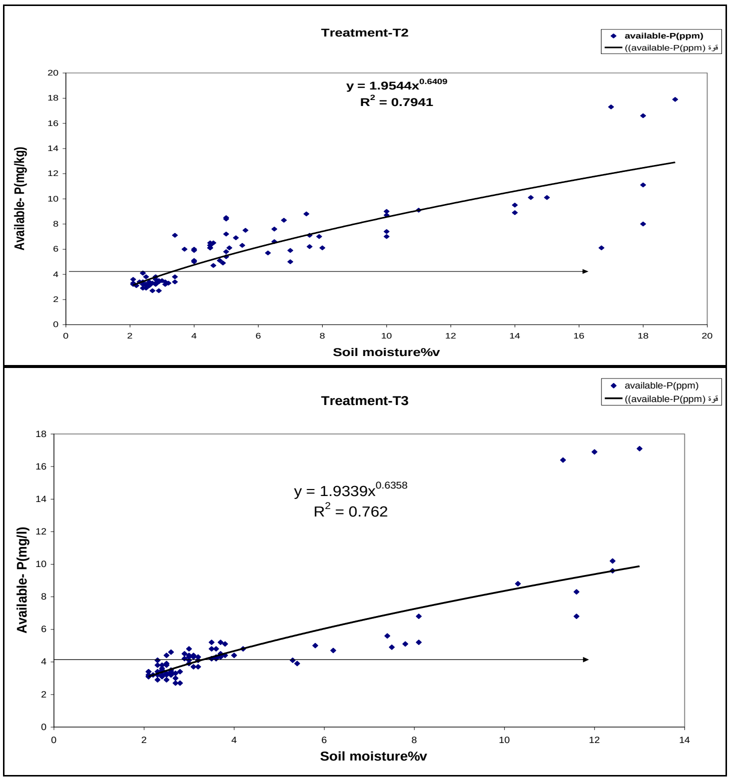

Fig. 6:cont.

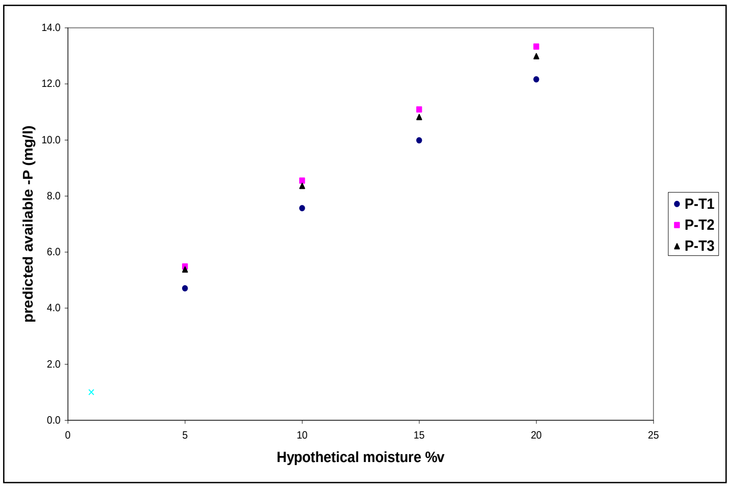

Fig. 7: Relationship between hypothetical moisture contents and available-P.

CONCLUSION

Soil moisture distribution and the wetted radius under continuous application are higher than that under intermittent application. On the other hand, soil salinity decreased with continuous application rather than under the intermittent application treatments.

Available P concentration in the soil immediately surrounding the emitter was found to be higher in continuous application as compared with intermittent irrigation regimes.

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تأثير أساليب الإضافة من الري بالتنقيط على توزيع الرطوبة, الأملاح والفوسفور فى التربة

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اجريت تجربة فى تربة صحراوية مستصلحة حديثا وذلك لدراسة تأثير أساليب مختلفة من الإضافة بواسطة الري بالتنقيط على توزيع الرطوبة , الملوحة والفوسفور الميسر فى التربة.
كانت المعاملات تحت الدراسة هى الإضافة المستمرة ومعاملتين للإضافة المتقطعة. حيث تم إضافة حجم متساوي من المياه مقداره 4 لتر/ ساعة فى كل معاملة يوميا. أضيف الفوسفور لكل معاملة بتركيز متساوي فى مياه الري مقداره 45 مليجرام فوسفور/ لتر من حامض الفوسفوريك. تم عمل نظام شبكي بأبعاد 10 × 20 سم وهذه الشبكية تغطى ثلاثة نقاطات متجاورة فى كل معاملة وهى التى اختيرت لجمع العينات السطحية (0-20 سم) من نقط تقاطع هذه الشبكية لتقدير الرطوبة , الملوحة والفوسفور الميسر.

أوضحت النتائج ان توزيع الرطوبة فى خلال مسافات من النقاط تحت معاملة الإضافة المستمرة تكون اكبر منها فى حالة معاملات الإضافة المتقطعة. كما أظهرت النتائج أيضا زيادة القطر المبتل فى معاملة الإضافة المستمرة عنها فى معاملات الإضافة المتقطعة. نقصت ملوحة التربة فى معاملة الإضافة المستمرة بدرجة اكبر عنها فى معاملات الإضافة المتقطعة. أما بالنسبة للفوسفور فقد أظهرت النتائج ان تركيز الفوسفور الميسر فى التربة بالمنطقة المتاخمة للنقاطات كان اكبر فى حالة معاملة الإضافة المستمرة بالمقارنة مع حالتي المعاملة المتقطعة.

العلاقة بين نسبة الرطوبة بالتربة والملوحة تم وصفها بمعادلات آسية تناقصية بينما أمكن توضيح العلاقة بين رطوبة التربة وتأثيرها على الفوسفور بعادلات آسية تزايدية.

J. Agric. Sci. Mansoura Univ., 32 (8), August, 2007
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