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Hydraulic Studies of Drip Irrigation System under Using Low Quality Water Conditions II- Moisture and Salinity Distribution Patterns

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Abstract
Water characteristics have the majority effect on moisture and salinity distribution. Therefore, the aim of this study wfas to evaluate the distribution of moisture and salinity under drip irrigation system and saline-water conditions. Field experiment was carried out at Research and Production Station, NRC, Nubaria District, El-Beheara Governorate, Egypt, during 2015/2016 growing season to study the effect of the selected emitter's types under different irrigation water salinity on the water and salt distribution patterns. The experiment was conducted under three emitter types [Non pressure compensating 1emitter (NPC1), Non pressure compensating 2 emitter (NPC2), and Non-pressure compensating 3 emitter (NPC3)] under water salinity (345, 2000, and 4000ppm).

Keywords: Emitter type, water salinity

Introduction

Countries in arid and semi-arid regions, such as Egypt, are concerned by reduction of fresh water resources allocated to agriculture, which led Egypt Government to direct their effort toward enhancement the water use efficiencies for available water and looking for another low quality source**(**Abu-Zeid, 2003 and Attia, 2004).Drip irrigation is widely known as the most efficient irrigation system that save a lot of water and overcomes the problem of losing water through deep percolation (Nakayama and Bucks 1986).Drip irrigation is particularly suitable for water of poor quality (saline water). Dripping water to individual plants also means that the method can be very efficient in water use, so it is most suitable when water is scarce (FAO, 1985, 1992; 2002).

In addition that drip irrigation only wets part of the soil root zone as compared with other irrigation methods. This may be as, low as 30% of the volume of soil wetted by the other methods. The wetting patterns which develop from dripping water onto the soil depend on emitter discharge and soil type. Water distribution in soil irrigated with surface drip irrigation system depends mainly on many factors (soil properties) as well as the system hydraulic properties and the amount of water applied per irrigation (Clark, et al., 1993) and water uptake by plants (Assouline, et al. 2002). The best management of the drip irrigation system is to either control or adjust to as many of these factors as possible.

The emitters deliver water at a desired rate near the plants. Though the system slowly and partially wets the soil near the plant root zone, but, it is practically difficult to apply the equal amount of water to all plants within a field unit. Therefore, in most cases, even a well-designed system gives poor uniformity as a consequence the yields are pretentious (Bhatnagar and Srivastava, 2003). Since, frequent application near the plants is ensured (Youngs*et al.*, 1999) hence; the conveyance and the other conventional losses such as deep percolation, runoff and soil water evaporation are minimal as water is conveyed through a network of pipes.

Mizyed and Kruse (2008)
Mentioned that a best and desirable feature of drip irrigation is that the uniform distribution of water is possible, which is one of the most important parameters in design, management,

and adoption of this system. But, due to manufacturing variations, pressure differences, emitter plugging, frictional head losses, irrigation water temperature changes, and emitter sensitivity results in flow rate variations even between two identical emitters.

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Materials and Methods
Field experiment was conducted in Research and Production Station, NRC, El-Nobaria District, El-Beheara Governorate, Egypt, in 2015/2016 to study the effect of selected emitter's types under different water salinity, on moisture and salinity distribution patterns. The soil of this site is sandy loam textured. The total area of the experiment was 540 m^2 and divided into nine main plots as shown in Figure (1). The system consists of the following components:

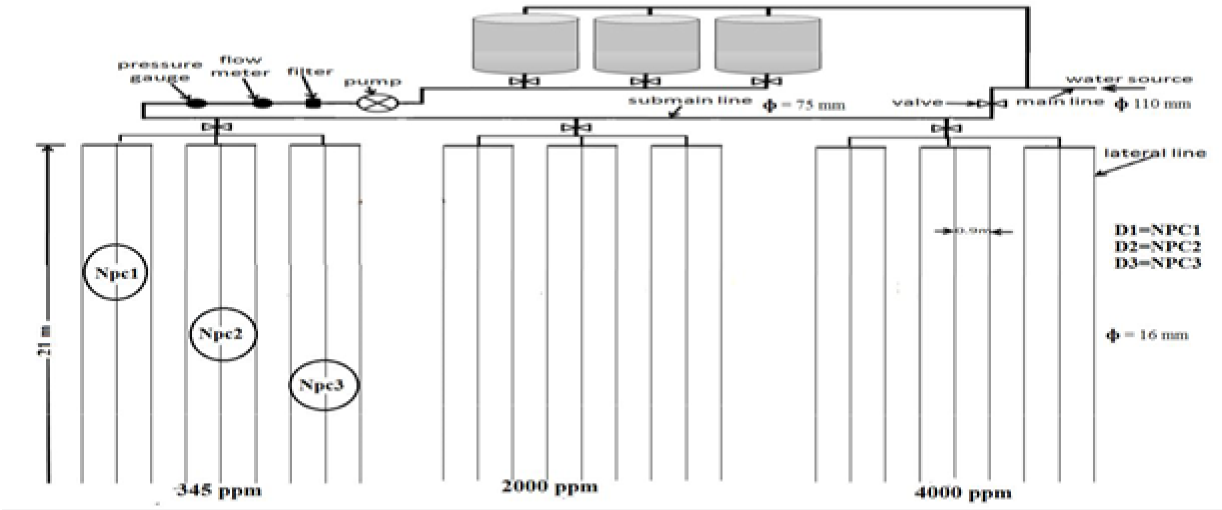

Fig. 1: Surface drip irrigation system components.

a) **Tank**: Three Polyethylene's, 1 m^3 tanks with a float inside was connected to the control head unit. The tanks are being filled with water through 63 mm PVC pipe - 6 bar, derived from the main line of the farm.

b) **Pumping unit**

Pump	**Motor**
Type: 4AMP180L4MY5	**Type:** NT65-400/390,4IB-W2, 522356/15
RPM: 1450 – 50 HZ.	**Power:** 22 KW.
Pressure: 5.5 bar.	**Voltage:** 380-680 V- 3 PH.
Flow rate: 70m3/h	**Efficiency:** 90%.

c) **Control head unit**
It is located at the water inlet and consists of:-

- Injection unit: venture PE of 2", the range of suction capacity 34-279 l/h.
- Filter: screen filter 1.5" (one unit), 155 mesh, Max. Flow 7.2m^3 \ h and maximum pressure ≈70 bar.
- Spring brass none return valve: 2inches.
- pressure gauges: 0-10 bar
- Control valves: diameter 2 inch –6 bar – UPVC material.
- Flow meter.

d) **Mainline:** A PVC pipe of 110 mm diameter connects the control unit for conveying the water to sub-main lines.

e) **Sub main lines:** A PVC pipe of 75 mm diameter derived from the main line to feed the manifold lines.

f) **Lateral lines:** A PE pipe of 63 mm diameter connects to the sub-main lines to feed the group of risers.

g) **Emitters:** Three types of emitters were used in this experiment Non pressure compensating (NPC), non-pressure compensating and pressure compensating(PS)and Line source (LS) as follows: NEIN-ETF (NPC1-PS),GR (NPC2- LS) and KATIF RivulisPlastro 201 (NPC3-PS), regarding to the emitter model and emitter type, respectively.
Soil samples were taken by screw auger at three places besides lateral line (10, 20, and 30 cm) and 5 depths (5, 10, 15, 20, and 25 cm) in three different positions along the lateral line beforeirrigation as well as after irrigation for all treatments. Soil samples were resolved to measure soil moisture (on a weight basis) and salt distribution (in 1:1 soil/water extract) in the two directions, vertical and horizontal. Soil salt was measured in extracted 1:1 (soil: water). Data were drawn using SURFER 10.

Results and discussion
Moisture distribution patterns
Water movement and hence its distribution pattern differs regarding the irrigation method, especially under drip irrigation compared with other surface irrigation method. Under drip irrigation, in addition to its high application frequency, water is applied at separated points on the surface of the soil rather than over the total area, so thesoil is wetted in a cone shape like axially symmetric pattern rather than in one-dimensional fashion. However, the

wetting front and moisture distribution depend upon the discharge rate and application time.
The wetting patterns under the emitters are characterized by the depth of wetting front under emitter and the radial wetting front at the surface. As shown in Figures (2, 3 and 4) both variables are influenced by the discharge of emitter that related mainly to its types and application rate or volume of applied irrigation water. Also, water quality could play an important role in water distribution, especially in the horizontal direction as shown in Figure
(2) With the application of the same amount of irrigation water the dimensions of the wetting area in both vertical and horizontal direction are markedly varied with the variation of emitter discharges and types.

Also, with increasing salinity in water, wetting front reached almost 20 cm in depth and almost 30 cm in the horizontal direction, and a wetting front reached more than 25cm in a horizontal direction away from the emitter's line, could be related to the fresh water.
Increasing salinity in water up to 2000 ppm resulted in the formation of the wetting front that has a higher width and moved downward more than 25 cm which may lead to exposing the irrigation water to move beyond the active area of root zone especially at the early stage of growth. Additionally, increasing salinity in irrigation water could increase water density and water diffusivity was affected also by water salinity, so spread water horizontally in the surface layer of the soil was expected.

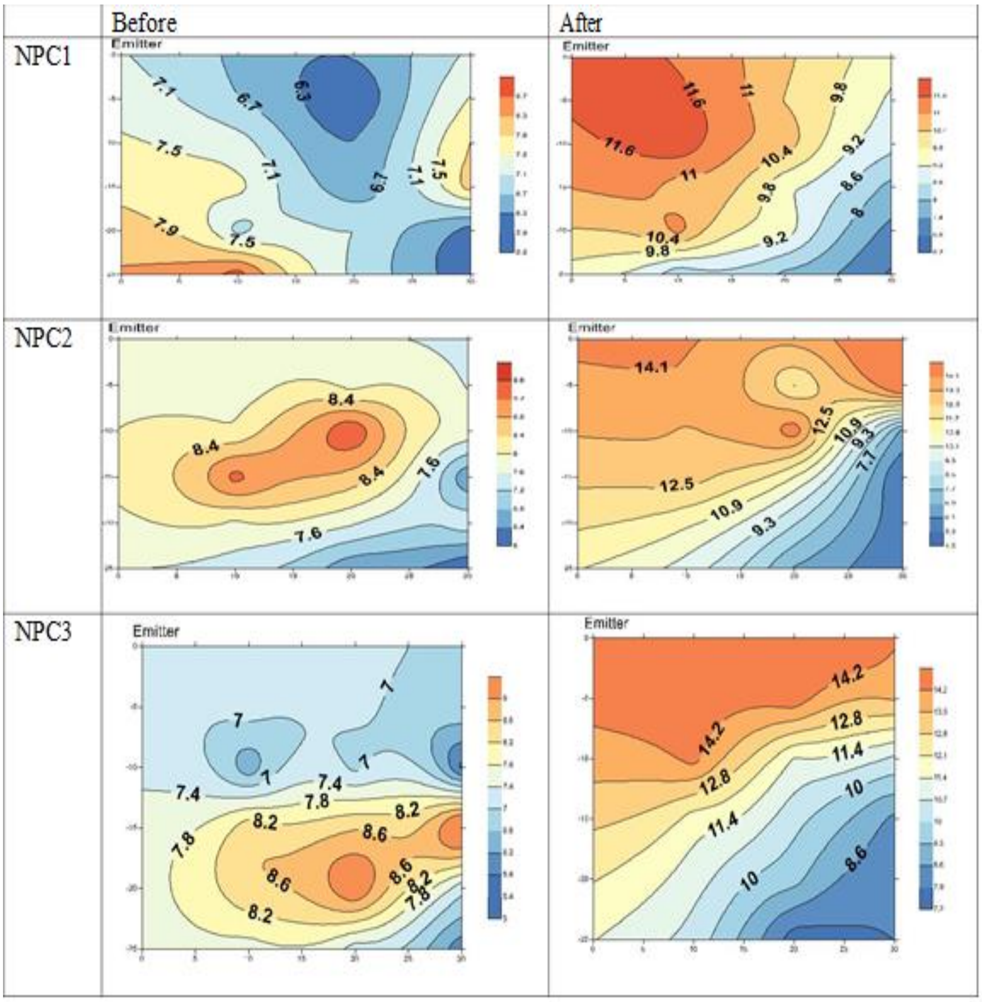

Fig.2: Effect of emitter types on the water distribution before and after irrigation process (canal water-345 ppm).

Emitters of high discharge rate NPC3 caused water runoff on fine textured soils, and emitters NPC1 is recommended to use under this condition. On the other hand, emitters that could be used in sandy soils in ascending order NPC1>NPC2>NPC3 relative to their distribution uniformity. The soil moisture content in the wetting area of 0.3 m depth underneath the drippers was ranged between 5.5 and 13.3 %. With increasing the emitter discharge and using saline irrigation water up to 345 ppm, the size of the wetting front become more in both horizontal and vertical direction. The wetting front that has 6.5 % reached 30cm away from the emitter at the soil surface in a horizontal direction and became wider than 50cm at the depth of 40 cm underneath the emitter as shown in Fig. (3).
After irrigation using the saline irrigation water applied at the same discharge rate the wetting front that has low water content equal to 9.5 % reached 20 cm in the horizontal direction and more than 25 cm in the vertical direction. With increasing the amount of irrigation water, the effects of initial water contents on the movement of the wetting front and water distribution become more pronounced.

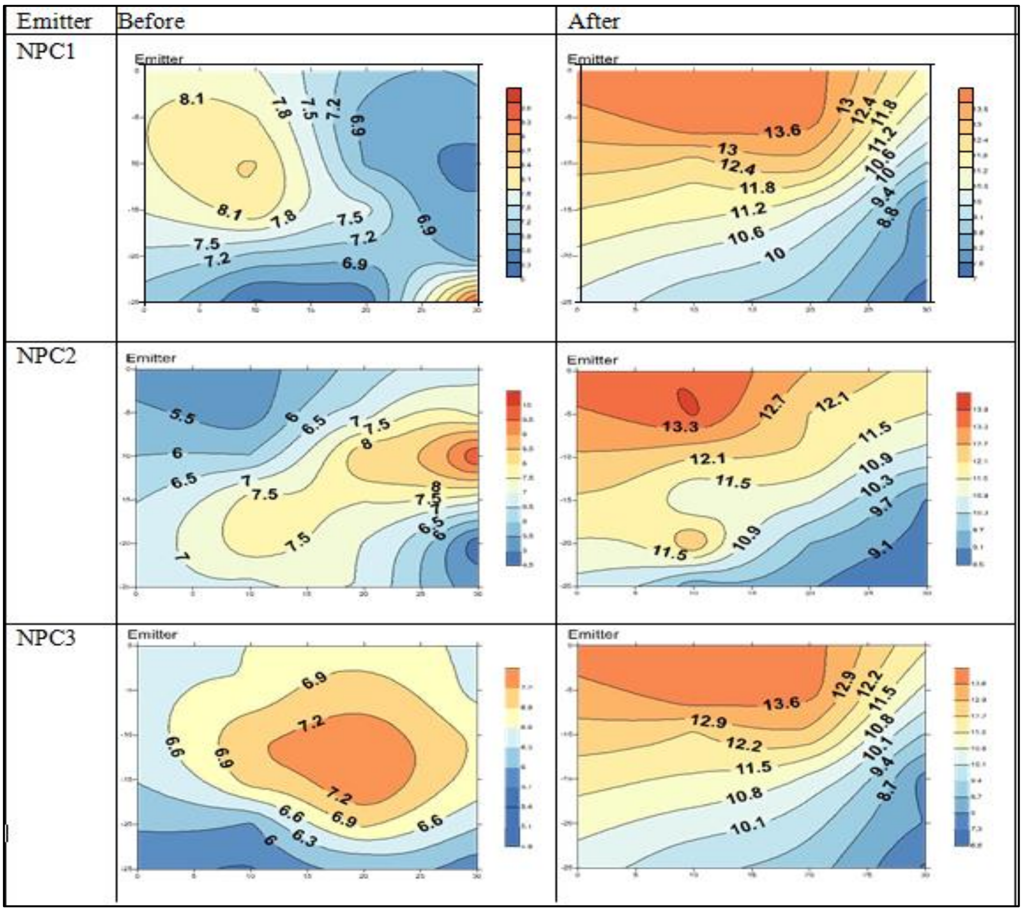

Fig. 3: Effect of emitter types on the water distribution before and after irrigation process (2000 ppm).

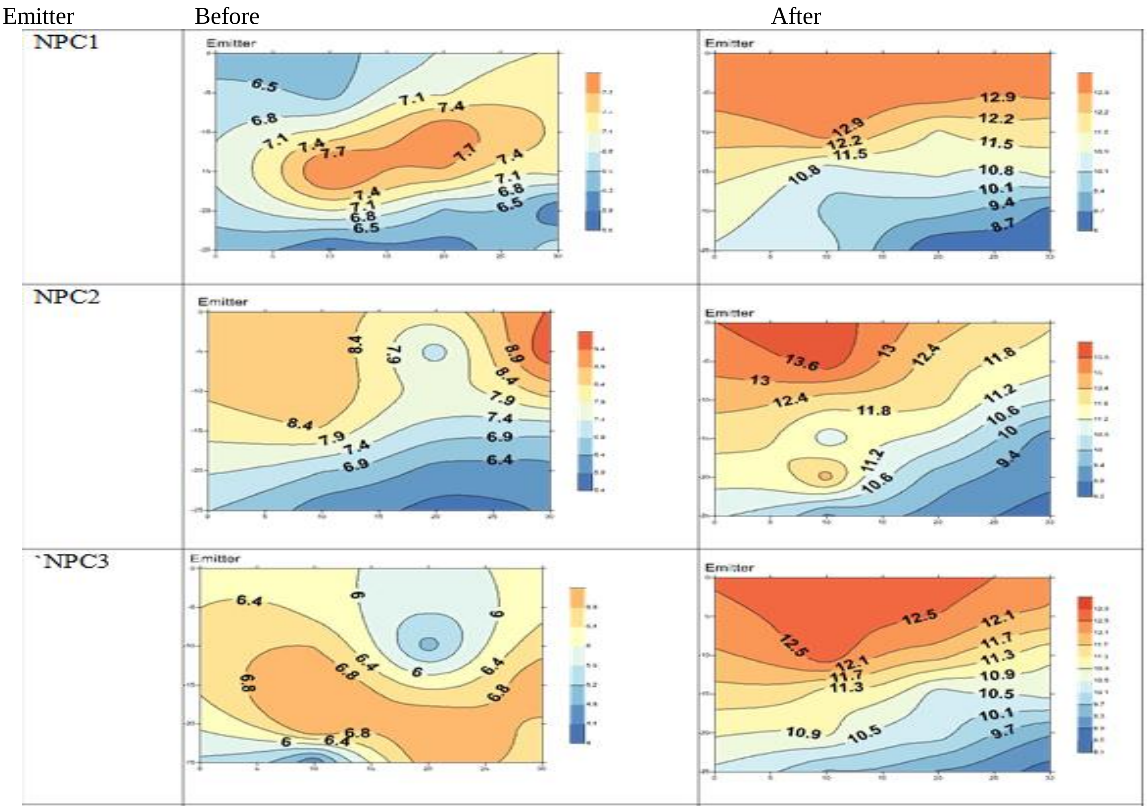

Fig. 4: Effect of emitter types on the water distribution before and after irrigation process (4000 ppm).

The wetted front that has high water content (more than12.3 %) reached 25 cm in the horizontal direction and more than 25 cm in the vertical direction with increasing the amount of irrigation water. Resulted data confirmed that the point that for managing the water content in root zone wetted area under emitter, it is suitable to believe the initial water content in the root zone before new irrigation process.

Salt distribution patterns

Salt distribution under drip irrigation system reflected wetting patterns during irrigation process and consequently distribution of soil water content. Wetting pattern under emitters just often irrigation, show that soil water content varied regarding water quality and emitter types. The wetted soil is near the emitter and the driest area is at the periphery of the wetted pattern. Also, Hanson and May (2007) mentioned that root distribution under emitter contributed in wetting patterns. The roots of crops were highly concentrated near emitters (the zone of wettest soil); if the emitter placement coincides with plant root.

Under irrigation with saline water (2000 and 4000 ppm) resulted in relatively low salinity levels in the area extending downward from the emitter and larger salt accumulation in the areas among emitter and close to the front of the bed for the investigated soil as shown in Figure (5, 6 and 7).The low salinity water extended further horizontally in the soil profile as shown in Figure

(5) While it is flat and moderately flatas shown in Figure (6; 7) relative to the moisture content in different soil layers before irrigation. Under DIS using saline water (4000 ppm) salt accumulated in the surface layer (before irrigation) while, it is concentrated in the outset root zone.

The upward flow of salinity may or not affect the salinity of root zone area, depending on the salinity of both irrigation water and subsurface layer texture. A relatively uniform soil salinity profile was found either before or after irrigation. Where the water was the same salinity but the soil salinity differs, the new soil salinity varied considerably with distance from emitter as shown in Figure (7) with a relatively low soil salinity level near the emitter.

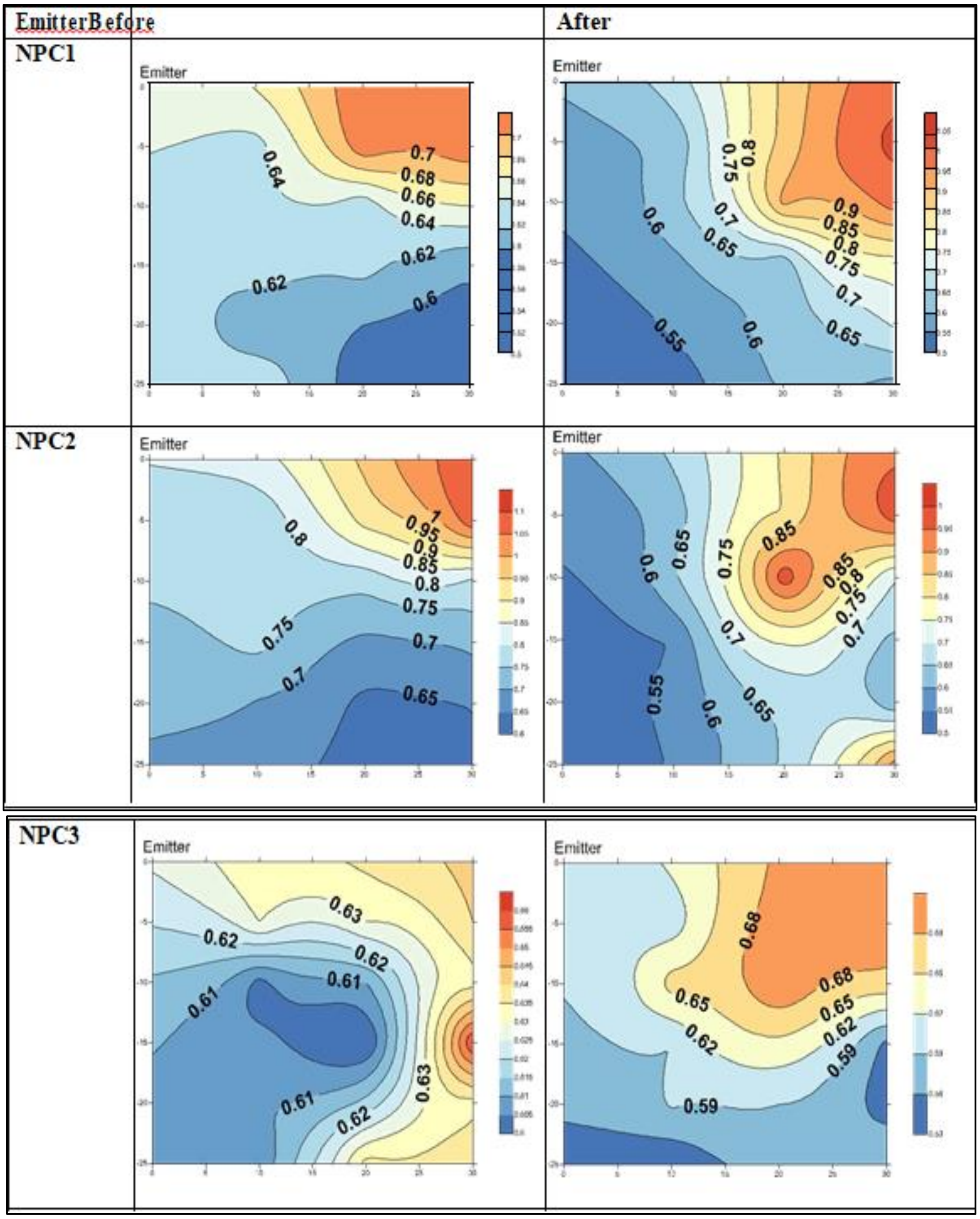

Fig. 5: Effect of emitter types on the salt (dS/m) distribution before and after irrigation process (canal water-345 ppm).

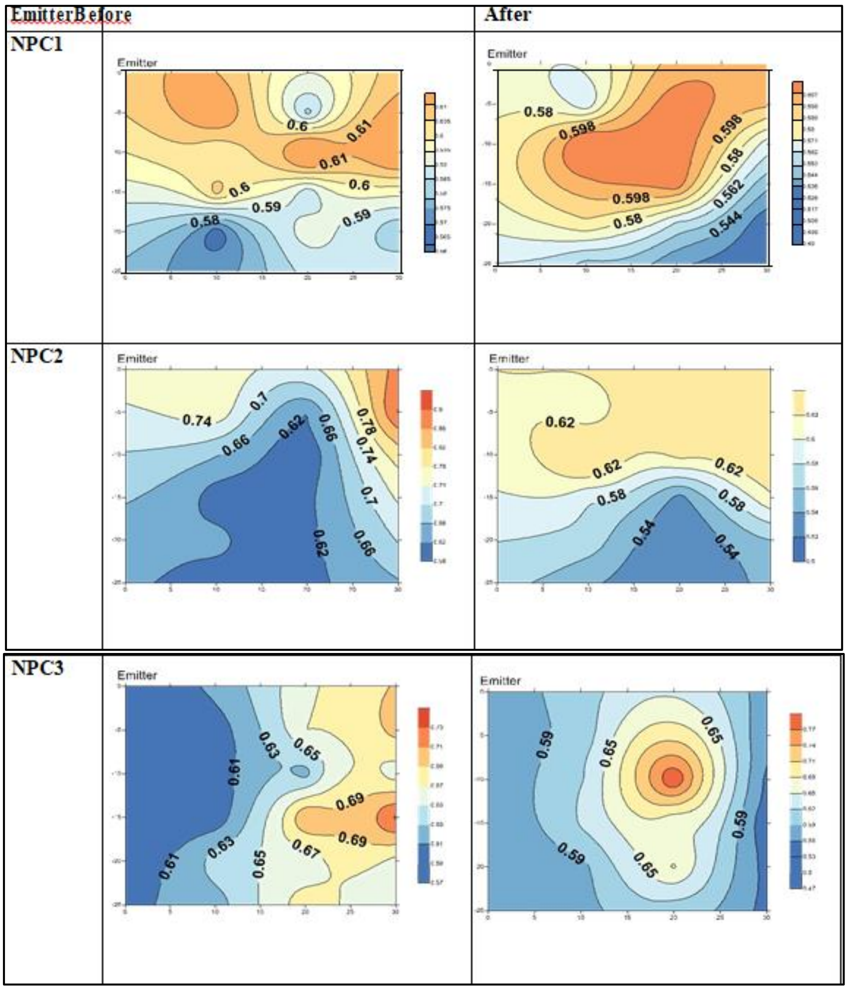

Fig. 6: Effect of emitter types on the salt (dS/m) distribution before and after irrigation process (2000 ppm).

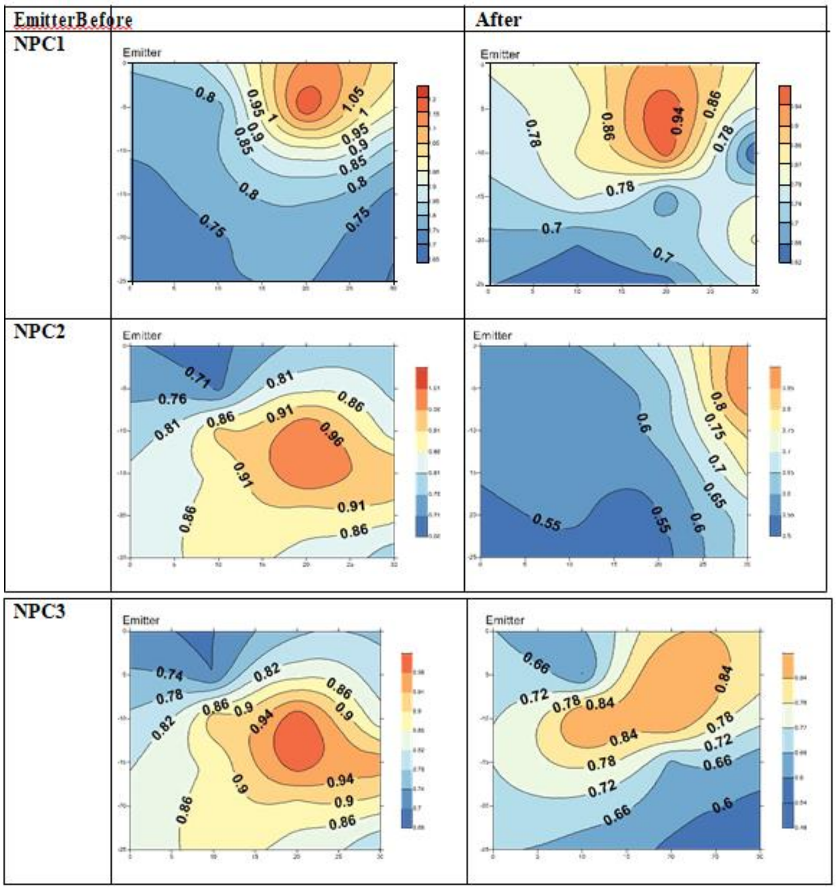

Fig. 7: Effect of emitter types on the salt (dS/m) distribution before and after irrigation process (4000 ppm).

The effect of different emitter types and saline water on growth and yield of turnip crop:

Table (1) illustrated the impact of the emitter's type and different water salinity on the turnip crop growth characters such as plant height, leaf length, biological weight for the whole plant and yield characters (tuber weight, tuber volume; tuber diameter).

Table. 1: The effect of different emitter types and saline water on growth and yield of turnip crop

Emitter type	Salinity	Plant length (cm)	Leaf length (cm)	Bio-weight g/plant	Tuber weight g/plant	Tuber volume cm^3	Tuber diameter cm
NPC1	345	55.83	48.33	781.06	489.04	506.67	7.77
	2000	54.22	46.45	625.98	453.97	488.33	7.50
	4000	49.00	47.00	634.12	367.98	386.67	6.08
NPC2	345	48.42	41.50	600.52	416.39	435.00	6.92
	2000	49.22	42.25	592.00	391.53	366.67	6.97
	4000	48.00	43.50	608.93	399.76	415.00	7.67
NPC3	345	48.42	41.50	600.52	416.39	435.00	6.92
	2000	49.22	42.25	592.00	391.53	366.67	6.97
	4000	48.00	43.50	608.93	399.76	415.00	7.67
LSD 5%		0.12	0.23	3.41	4.36	12.35	0.14
Mean PPM	345	50.50	43.56	700.72	415.22	431.67	7.27
	2000	49.35	42.23	576.78	414.54	434.44	7.02
	4000	48.67	45.42	561.91	402.85	428.33	7.11
LSD 5%		0.87	0.31	12.35	1.2	2.05	0.07
Mean	NPC3	53.02	47.26	680.39	437.00	460.56	7.12
Emitter type	NPC2	48.54	42.42	600.48	402.56	405.56	7.18
OT		46.96	41.52	558.55	313.06	334.44	6.87
LSD 5%		1.25	0.47	22.34	15.36	66.35	0.09

Data revealed that the highest values were recorded at (NPC1) after irrigation by fresh water (345 ppm) for all studied plant characters. While NPC2 and NPC3 took the same trend where the highest values were obtained under saline irrigation water 2000 ppm (plant height) and 400 ppm (leaf length, biological weight; tuber diameter) and tuber weight and tuber volume under 2000 ppm. This finding is agreed with those obtained by Munns (1993; 2002) and Hanson *et al.* (2000), who reported that salinity stress depresses plant growth and development at different physiological levels. The decrease in plant growth by salinity stress might be related to adverse effects of excess salt onion homeostasis, water balance, mineral nutrition, and photosynthetic carbon metabolism.

According to the influence of emitters' type on the investigated plant characters, one can notice that there is one trend where the highest values were attained after NPC1 except tuber diameter and the lowest values were obtained after NPC3 emitter. Also, there were significant differences between any two emitters, except between NPC3 and NPC2 for tuber diameter.

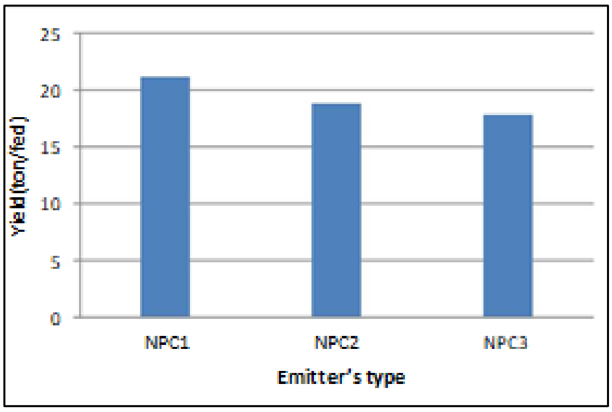

Fig. 8: Effect of different emitter types on growth and yield of turnip crop.

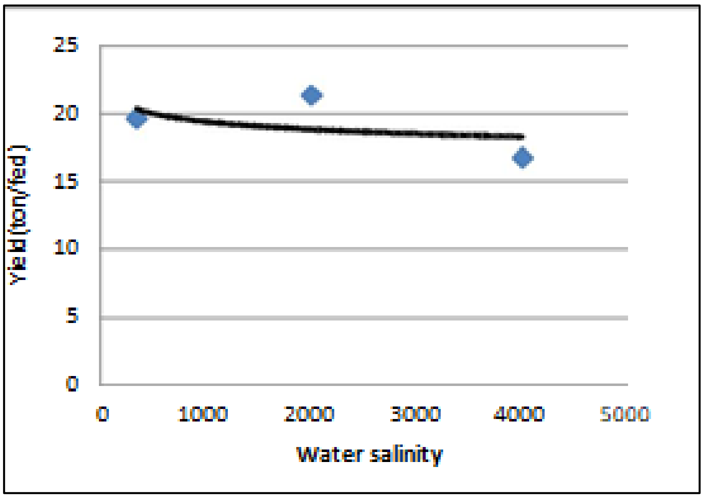

Fig. 9: Effect of different water salinity on growth and yield of turnip crop.

Regardless emitters' type, water salinity had a negative effect on the studied plant parameters, where the highest and lowest values were recorded in fresh water and 4000 ppm irrigation water, except leaf length (2000 ppm). Also, it could estimate the rate of change when comparing fresh water with saline one and the obtained values were 2.3, 3.1, 21.5, 0.2, - 0.6; 3.6 % when comparing fresh with 2000 ppm for the previous plant characters and when comparing fresh with 4000 ppm the values were 3.8, -4.1, 24.7, 3.1, 0.8 and 2.3 %, respectively. Our data

supported by Osman *et al.*(2014) who found that increasing water salinity up to 4000 and 5000 ppm associated with a reduction for most plant characters of pear seedlings in two seasons Also, Table (2) and recorded that the effect of both two investigated factors (emitter's type; salinity), data pointed out that DU under NPC3 without change and its value was 0.91 under using water salinity treatments, but NPC1 had the highest value more than the other two types with values 0.94 (345; 2000 ppm) and at WS 4000, the value was 0.93. However, NPC2 emitter got a variation between studied water salinity and values ranged from 0.92 (2000 ppm) and 0.88 (4000 ppm).

The effect of different emitter types and saline water on water use efficiency of turnip crop:

Table. 2: Water requirement of the turnip crop.

Month	**Nov.**		**Dec.**		**Jan.**		**Feb.**
ETo (mm/day)	2.88		2.49		1.65		2.54
Stage	20	8	22	9	26	5	10
	Initial stage (20 days)	Development stage (30 day)		Mid –season (35 day)		Late season (15 day)	
Kc	0.5	0.8		1.10		0.6	
ETc (mm/day)	1.44	2.30	1.99	2.74	1.82	0.99	1.52
ETc (m^3 /day / Fed)	6.1	9.7	8.4	11.5	7.6	4.2	6.4
ETc (m^3 / stage/Fed)	122	543		668.5		159	
Etc total (m^3/season/Fed)	1492.5						
IR (m^3/season/Fed)	$= \frac{1492.5\times(1+0.15)}{0.9} = 1907.1$						

This finding is agreed with those obtained by Munns (2002), who reported that salinity stress depresses plant growth and development at different physiological levels. The decrease in plant growth by salinity stress might be related to adverse effects of excess salt onion homeostasis, water balance, mineral nutrition and photosynthetic carbon metabolism.

With respect to DU values, the water amount applied to the crop during the growth season varied from 1824 m^3/fed to 1907 m^3/fed at operation pressure 1 bar. The Same table showed root yield and Water use efficiency as affected by water salinity and emitter's type of turnip crops, it's clear that NPC1 emitter has a superior effect and recorded the highest value which ranged from 18.12 ton/fed (4000 ppm) and 23.43ton/fed (354 ppm) and 12.8; 9.1 kg/$m^3$for 345 and 4000 ppm, respectively at 1 bar operation pressure. While comparing WUE for examined emitters, NPC1 had a primitive effect and recorded 14.5 and 17.4 % more thanNPC2 and NPC3 respectively.

Table. 3: Distribution uniformity, Yield, and water crop productivity of turnip plant as affected by emitter types and water salinity under 1.0bar operation pressure.

Emitter type	**Salinity**	**Plant length (cm)**	**Leaf length (cm)**	**Bio-weight g/plant**	**Tuber weight g/plant**	**Tuber volume cm^3**	**Tuber diameter cm**
NPC1	345	55.83	48.33	781.06	489.04	506.67	7.77
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	345	50.50	43.56	700.72	415.22	431.67	7.27
Mean PPM	2000	49.35	42.23	576.78	414.54	434.44	7.02
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LSD 5%		1.25	0.47	22.34	15.36	66.35	0.09

With respect to salinity effect, it's clear to mention that, increase salinity associated with root yield and WUE. The rate of reduction in yield and WUE relative to salinity were 11.5, 2.5 % and 20.1, -3.5 % for irrigation water salinity 2000 and 4000 ppm relative to control one (345 ppm).

Table (2) showed the interaction effect between emitters' type and water salinity on the economic yield and water use efficiency (WUE). Data noticed that root production of turnip was reduced from 20.66 to 16.45, 23.4 to 18.12 and 19.903 to 15.71 ton/fed for fresh and 4000 ppm after NPC3 and NPC1 respectively.

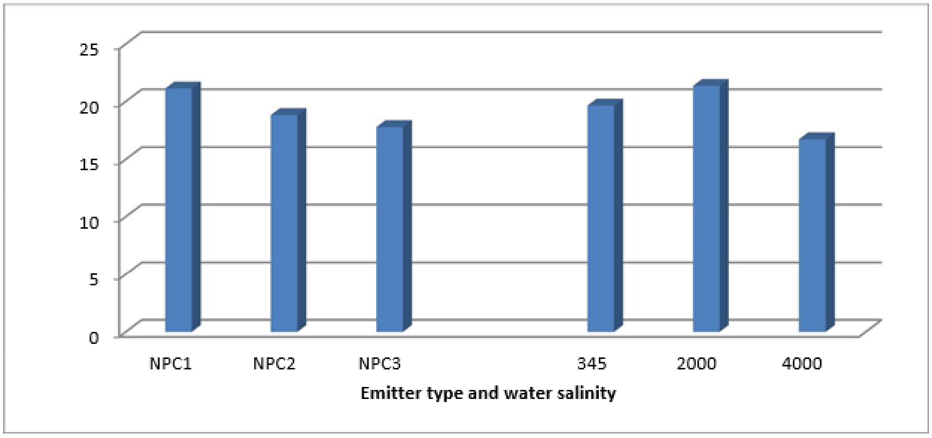

Fig.10: The effect of water salinity and emitter's type on yield and WUE of turnip crop.

With respect to the water use efficiency (WUE) as affected by both emitters type and water salinity,Table (3) and Figure (10) revealed that emitters NPC1 recorded the higher value followed by the other two investigated types with anasignificant difference and there is no significant difference among them.

Figure (10) showed a simple comparison between different water salinity inside and among examined emitters and their effect on WUE wherethe highest yield appeared in fresh water with increase percentage 21 and 33 % as compared with 2000 and 4000 ppm water salinity, respectively. Whereas, the highest value of turnip yield was 23.43 ton/fed at NPC1 with increase percentage about 19 % as compared with both examined emitters.

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