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The Effect of Electromagnetic Forces and Saline Water on Hydraulic Properties of Drip Irrigation System and Soil Salinity Distribution

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Abstract

The aim of the present work is to designelectro-magnetic unit and evaluation of resulted magnetic force of different saline waters on the germination of different plant seeds laboratory and yield of turnip in a field experiment. The field experiments were conducted at Research and Production Station, El-Noubaria, El-Behaira Governorate (NRC), in split-plots design. Results could be summarized as following: Operating time of the uniformity test was one hour and distribution uniformity estimated for known the validation of drip irrigation system for its application in the experimental work were0.84; 89.92% (345 ppm), 0.96; 97.48 % (2000 ppm) and 0.72; 82.36 % (4000 ppm) for DU and EU, respectively. The wetting patterns under the drippers are characterized by the depth of wetting front under the dripper and the radial wetting front at the surface. Both variables under investigation (magnetic force and water salinity) are affected positively by water and salt distribution either before or after irrigation process regarding mainly to the discharge of dripper, application rate or volume of applied irrigation water and water salinity.

Keywords: Design, Magnetic force, saline water, drip irrigation, uniformity, moisture distribution, salt distribution, turnip, yield

Introduction

The lack of water is a big problem facing Egypt is likely to worsen in the future as a result of continuous population increasing on an ongoing basis, and climate change and the deterioration of the quality of water resources, since the majority of renewable water resources in Egypt is mainly used agriculture mainly, but other types of water resources (non-renewable) not can benefit from them, but the costs are too high, and is what makes their use impossible choice, as it is likely to cause competition from other sectors in reducing agriculture's share of water resources in general. Therefore, it became necessary to search for new ways to address the salt water used in agriculture as Egypt has an abundance of salt water due to its regional and geographical and most important of these methods is using the magnetic in salt water treatment.

Drip irrigation offers an excellent alternative to sprinkler irrigation for vegetable and fruit growers and typically use 30-50 % less water than. Drip irrigation systems can apply frequent and small amounts of irrigation water at many points of a field surface/subsurface near the plants (Youngs *et al.*, 1999). Typical requirements for a drip system include a pump, filters, chemical/ fertilizer injectors, main and sub-main lines, laterals and emitters. Accurate emitter manufacturing is necessary in order to achieve a high degree of system uniformity. However, the complexity of emitter and their individual components make it difficult to maintain precision during production (Hezarjaribi *et al.*, 2008). The emission uniformity is essential for the determination of total depth of irrigation. An efficient irrigation system must apply water uniformly throughout the field (Changade *et al.*, 2009). A successful uniform application through drip irrigation system depends on the physical and hydraulic characteristics of the drip tubing (Al–Amoud, 1995). In drip irrigation systems, uniformity can be evaluated by direct measurement of emitter flow rates.

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The emission uniformity (EU) criterion is used largely to design micro irrigation laterals. The EU is affected by the variation of pressure head due to elevation changes and head losses along the lines, as well as by water temperature, manufacture's variation, grouping of emitters, clogging, variability in soil hydraulic characteristics, and emitter spacing (Singh *et al.*, 2007; Almajeed and Alabas, 2013). The relationship between the emitter flow rate and the static pressure of the pipe is very important to a drip irrigation system. This relationship is used the most important properties in drip tubing irrigation systems are uniformity; anti-clogging unregulated dripper varies with inlet water pressure rather than friction losses along the laterals, both in designing the desired emitter flow path (Al-Amoud, 1995;Provenzano *et al.*, 2003). The efficient utilization of irrigation water is possible by the adoption of the high efficient irrigation system, such as drip irrigation systems. Drip irrigation method is the best method that has been used in the world among the other irrigation methods because of its good and high uniformity. Drip irrigation system can apply frequent and small amounts of irrigation water at many points of a field surface/subsurface near the plants (Youngs *et al.*, 1999). With drip irrigation, plant water, and fertilizer requirements can also be applied to the plant root zone with minimum losses, maintaining steady moisture in the soil profile. In addition, drip irrigation system has the advantage of fitting to difficult topography (Wei *et al.*, 2003).

The efficiency of a well-designed drip irrigation system can reach nearly 100 %. Also, it can potentially provide high application efficiency and achieve high application uniformity. Both are important in producing uniformly high crop yields and preserving water quality. The hydraulic and topographic situation of the system causes variation in pressure heads at each outlet. Therefore, it is necessary to study the effect of variable operating pressure on emitter discharge at individual outlets. As the pressure variation increases, the uniformity and application efficiency of the system is reduced (Solomon, 1984) which increases the water losses. Evaluation of hydraulics of drip irrigation system helps in improving the design of irrigation system and better control of irrigation water.

Under limited resources of freshwater and high demand for high-quality water allocated to agriculture led many countries (Egypt) to direct their effort toward enhancement the water use efficiencies for available water and looking for another low-quality source. Drip irrigation is widely known as the most efficient irrigation system that saves a lot of water and overcomes the problem of losing water through deep percolation (Nakayama and Bucks, 1986) who added also, that a small wetted bulb is created underneath each emitter. However, Aboulila *et al.* (2013) reported that water and salt distribution under drip irrigation method, with increasing competition for fresh water nowadays; there is also a need for greater use of low-quality water in agriculture.

Water distribution in soil irrigated with surface drip irrigation system depends mainly on many factors such as soil properties, as well as the system properties such as the discharge of 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. Acar *et al.*, (2009) reported there are parameters that affect the water distribution in both vertical and horizontal directions that could be summarized as follows: i) the volume of wetted soil, ii) the pattern of water front, iii) its area, iv) velocity. They addition, these parameters are intrinsic for designing and operating DIS. Moreover, they are affected by both the amount of irrigation water and the dripper's discharge, as well the soil hydro-physical characteristics.

The drippers deliver water at a desired rate near the plants, though the system is 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, aging, frictional head losses, irrigation water temperature changes, and emitter sensitivity results in flow rate variations even between two identical emitters. Uniformity distribution (UD) of water application means that all the plants receive an equal amount of water. In a poorly designed system, one cannot get good UD of water, thus it would either under irrigate or over irrigate his field. Under both cases, plants will either suffer the dry or the wet stresses (Phocaides, 2001). A system with a uniformity coefficient of at least 85% is considered appropriate for standard design requirements. The wetting patterns which develop from dripping water onto the soil depend on discharge and soil type.

As a matter of fact, moisture distribution resulted from some side movement of water in the soil profile away from the emitters point (Tagar *et al.*, 2010). Therefore, it is possible to irrigate with a much lower uniformity coefficient under many conditions without suffering from yield reductions.

The objectives of the present work are to design an electro-magnetic unit and evaluation of resulted magnetic force of different saline waters on the germination of different plant seeds laboratory and yield of turnip in a field experiment.

Materials and Methods

Salinity waters were collected from different wells to represent different salinity levels used with a final EC in the range of 345 to 4000 ppm was reached germination response to salinity levels was monitored visually at 24 hr intervals for the duration of the germination test. A grain was considered to have germinated if the radical exceeded 2 mm length. Water treatments were five salinity (canal water (345), 1000, 2000 and 4000 ppm) and fourth magnetic force (0, 800, 1000 and 2000 gauss) as well as untreated one.

Drip irrigation system was setup according to the treatments. The system consists of (pump: dab model JET 102M, Power 1.0 hp and discharge 0.6- 3.6 m^3h^{-1} and hmax

53.8 m, filter 0.5 inch, pressure gauges, flow-meter, and control valves, main line of PVC pipe of 32 mm, submain line of PVC 25mm and laterals of 16 mm diameter PE tubes lines with built in emitters (discharge of 4 Lh^{-1}at 1 bar operating pressure and 30 cm emitters spacing, The distance between laterals was 90 cm with 21 m long) as presented in Figure (1).

Field experiments were carried out in the Experimental Farm of Agricultural Production and Research Station (APRS), National Research Centre (NRC), El Nubaria Province, Egypt, sandy soil (latitude (30.69 N, 30.668 E, and mean altitude 31 m) above sea level).

The field experiment was a split-plot design. The main plots were magnetic forces treatments. Three magnetic forces treatments were used: zero, 1000 and 2000 Gauss. On the other hand, three salinity treatments (canal water 345, 2000 and 4000 ppm) occupied the sub-plots under turnip crop.

Soil and water analysis is in the following Tables (1, 2, and 3).

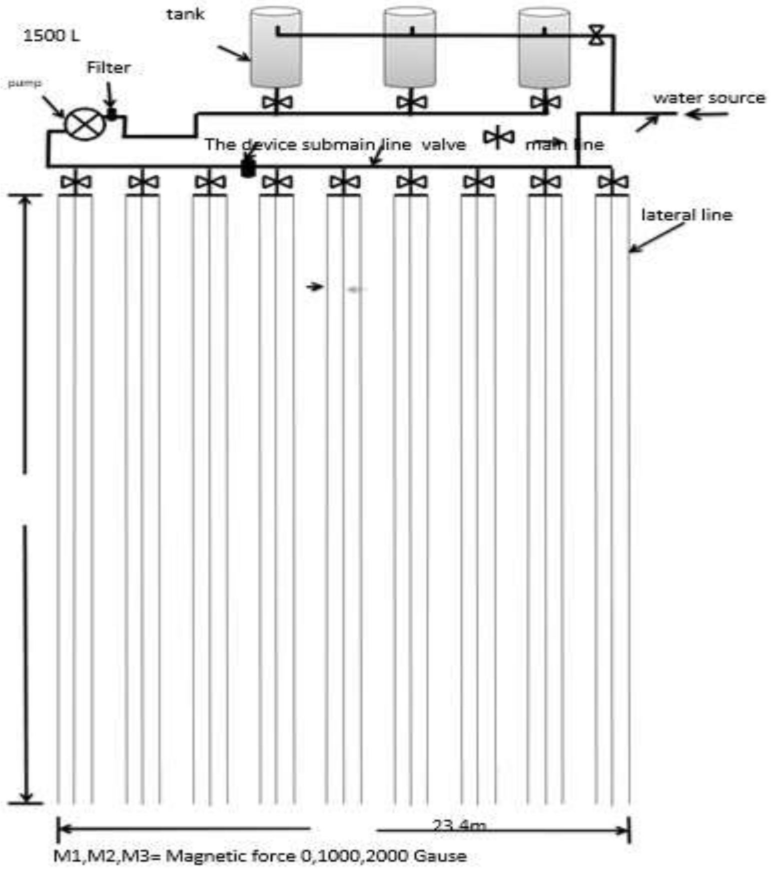

Fig. 1: Layout of the magnetic forces and water treated by the magnetic field in the field under drip irrigation system.

Table. 1: Soil physical properties of the experimental site.

Soil sample Depth(cm)	**Particle size distribution (%)**				**Texture class**	**FC**	**WP**	**AW**	**BD(g/cm3)**	**HC(cm/h)**
	Coarse sand	**Fine sand**	**Silt**	**Clay**		**(V/V %)**				
0-15	3.7	64.5	15.2	16.6	S	0.22	0.11	0.11	1.45	1.11
15-30	3.8	65.8	14.6	15.8	S	0.22	0.11	0.11	1.43	1.28
30-45	4.6	63.7	16.0	15.7	S	0.22	0.11	0.11	1.43	1.28
45-60	4.6	65.9	15.5	14.0	S	0.21	0.10	0.11	1.42	1.53

(*) Determined as percentage in (V/V %) cm3 Water/ cm3 Soil, (S): Sandy soil; HC: Hydraulic conductivity; and BD: Bulk density.

Table. 2: Chemical analysis of the soil.

Soil sample depths(cm)	**Cations (Meq/l)**				**Anions(Meq/l)**				**pH**	**E.C(dS/m)**
	Ca++	Mg++	Na+	K+	CO3--	HCO3-	Cl-	SO4--		
0-15	6.43	4.89	185.0	18.84	0	5.64	6.65	58.7	8.10	1.97
15-30	11.53	6.49	237.1	25.01	0	5.21	10.53	62.6	8.13	2.98
30-45	12.15	7.97	279.1	26.63	0	3.68	11.48	64.0	8.11	3.61
45-60	12.56	4.17	307.1	32.28	0	3.62	5.6	66.9	8.03	3.76

Table. 3: Some chemical properties of irrigation water.

Water sample	**pH**	**EC ppm**	**Soluble anions and cations (meq/l)**								**SAR**
			Ca^{++}	**Mg^{++}**	**Na^{+}**	**K^{+}**	**$CO3^{=}$**	**$HCO3^{-}$**	**$SO4^{=}$**	**Cl^{--}**	
Canal	7.34	474.88	2.01	1.68	2.88	0.85	0.0	0.47	3.01	3.94	2.12
Well	7.53	4160.64	21.23	18.28	23.35	2.15	0.0	0.53	28.24	36.24	5.25

EC:Electrical conductive; SAR: Sodium absorption ratio.

Soil Physical and Chemical analysis and irrigation water were measured with using the standard methods after Rebecca (2004) and shown in Table (1, 2, and 3). All the measured chemical parameters describe the status of the irrigation water and it can be used normally in irrigation. Water salinity treatments were prepared by dilution canal water with saline well.

Moisture and salinity distribution

Soil samples were taken by screw auger at three places besides lateral line (10, 20, and 30 cm) and5 depths (5, 10, 15, 20, and 25 cm) in three different positions along thelateral line before irrigationas well as after irrigation for all treatments. Soil samples were resolved to measure soil moisture (on aweight 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). And Data were drawn using SURFER 10.

Results and Discussion

The effect of saline water on hydraulic properties of drip irrigation system:

Operating time of the uniformity test was 60 minutes, the water volume of received water through 20 cans, which were put below randomized 20 (Built-in) GR drippers. Distribution uniformity estimated for known the validation of drip irrigation system for its application in the experimental work.

Table (4) and Figure (2) (in appendix) show that average of the lowest quarter of the Gauss (345 ppm) = 2.50 (l/h), and average of received water = 2.99 (l/h) and distribution uniformity=0.84. Emission uniformity =37+ (63*0.84) =0.8992=89.92 %.

Data in Table (5) and Figure (3) (in appendix) indicated that the lowest quarter of (2000 ppm) = 3.92 (l/h), and average of received water = 4.07 (l/h) and distribution uniformity = 0.96. Emission uniformity = 37 + (63*0.96) = 0.9748 = 97.48 %.

On the other hand one can notice that low quarter of (4000) = 2.63 (l/h), and average of received water = 3.63 (l/h) and distribution uniformity= 0.72. Emission uniformity =37+ (63*0.72) =0.823=82.36 % were shown in Figure (4) (in appendix).

This difference attributed to dripper clogging percent, uniformity evaluated one time, and the evaluation was in the end of season.

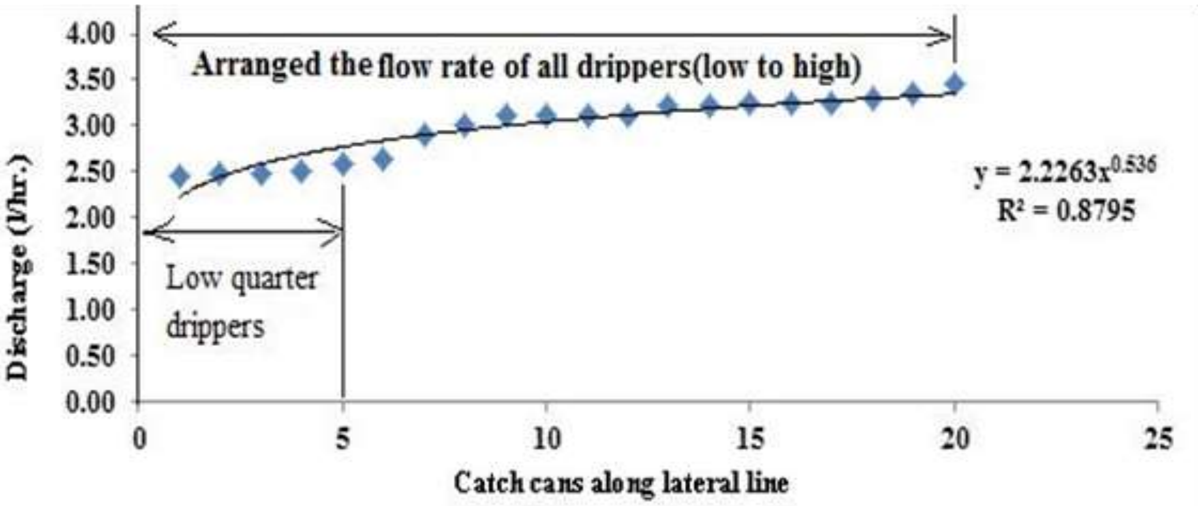

Fig. 2: Evaluate the distribution uniformity of drip irrigation by canal water (345 ppm).

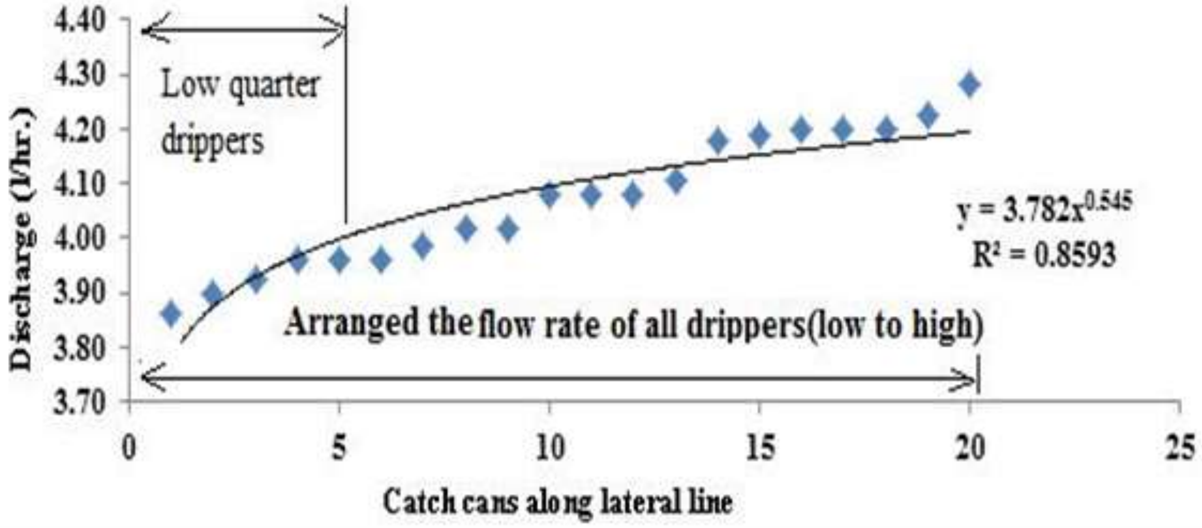

Fig. 3: Evaluate the distribution uniformity of drip irrigation by salinity water (2000 ppm).

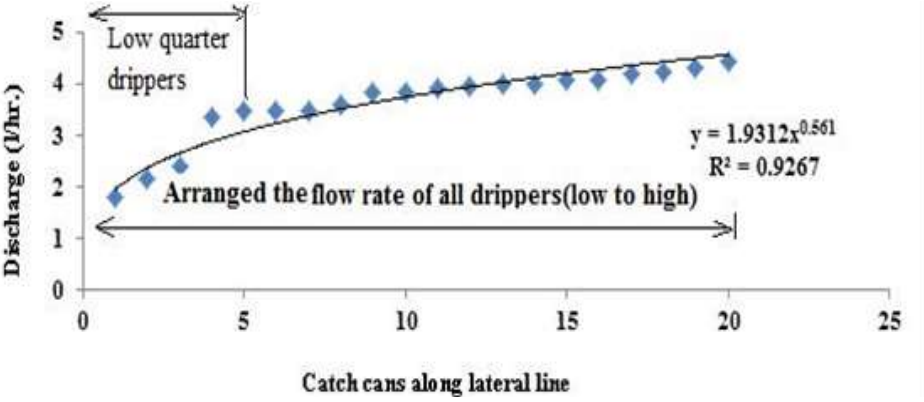

Fig. 4: Evaluate the distribution uniformity of drip irrigation by salinity water (4000 ppm).

Table. 4: Data for estimating distribution uniformity for drip irrigation system under different treated saline water.

Cans number	345 ppm	2000 ppm	4000 ppm
		Volume (l/hr)	
1	3.74	3.76	3.46
2	3.76	3.79	3.49
3	3.8	3.8	3.51
4	3.81	3.82	3.53
5	3.83	3.85	3.57
Mean of the lowest Q	3.79	3.80	3.51
6	3.84	3.89	3.75
7	3.85	3.9	3.76
8	3.87	3.91	3.76
9	3.86	3.94	3.78
10	3.91	3.96	3.79
11	3.93	3.97	3.8
12	3.94	4.01	3.81
13	3.87	4.05	3.83
14	3.94	4.1	3.84
15	3.91	4.11	3.95
16	3.93	4.13	4.01
17	3.99	4.15	4.06
18	4.18	4.17	4.05
19	4.22	4.2	4.08
20	4.24	4.2	4.11
Mean of the total Q	3.97	4.05	3.89
Emission uniformity	0.96	0.94	0.90

Moisture distribution patterns

The wetting patterns under the drippers are characterized by the depth of wetting front under the dripper and the radial wetting front at the surface. As shown in Figure (5) (in appendix), both variables under investigation (magnetic force and water salinity) are affected positively by water distribution either before or after irrigation process regarding mainly to the discharge of dripper and application rate or volume of applied irrigation water. With the application of the same amount of irrigation water, the dimensions of the wetting area in both directions are markedly varied with the variation of dripper discharges.

With the application of irrigation water quantity relative to the EU of dripper and/or irrigation system, the wetting front was around 20-30 cm in depth underneath the dripper and from 10 to 25 cm in a horizontal direction away from the dripper's line. With increasing the water salinity, the wetting front that reached almost 30 cm in depth and about 20 cm in the horizontal direction as shown in Figure (6) (in appendix). This means that decreasing salinity and increasing magnetic field (force) pushed the wetting front in both direction, but the movement of water away in the horizontal direction was more. Also, increasing the magnetic field (force) resulted in the formation of the wetting front that has higher water content and moved downward more than 30 cm which may lead to exposing the irrigation water to move beyond the active root zone area especially at the early stage of growth as shown in Figure (7) (in appendix).

These results are in agreement with what have been reported by Al-Qinna and Abu-Awwad (2001) who stated that for the same volume of water, the vertical penetration of wetting front decreased and the horizontal water movement increased as the water application rate increased. In the investigation, soil's (sandy loam) macro-pores are dominant and allow for fast downward flow especially when low salinity water is used (Ragheb *et al.*, 2011). This means that using high discharge drippers in drip irrigation system well resulted in overlapping the wetted zone in the horizontal direction, and in the same time may result to push the water deeply below the root zone. Also, Shlmpel ***et al.*** **(2002)** carried out an experiment by using micro-drip irrigation with perforated tube and resulted that the amount of water infiltrated vertically was more than that of horizontal infiltration in main root zone especially under the coarse textured soil.

With increasing the dripper flow rate and using saline irrigation water up to 345 ppm, the volume of the wetting front become more in both studied directions. The wetting front of treated saline water (2000 and 4000 ppm) reached 30 cm away from the dripper at the soil surface in a horizontal direction and became wider than 20cm at the depth of 25 cm underneath the dripper. These results are in agreement with what have been obtained by Elmaloglou and Diamantopoulos (2008) who found that the vertical component of the wetting front was greater for pulse than for the continuous irrigation for a time equal to irrigation duration. Additionally, after irrigation using the saline irrigation water applied at the same discharge rate the wetting front of low salt water reached 20 cm in the horizontal direction and more than 40 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, where the wetted front that magnetized saline water reached 30 cm in the horizontal direction and more than 30 cm in the vertical direction. Resulted data confirmed that the point that for managing the water content in root zone wetted area under dripper, it is suitable to believe the initial water content in the root zone before new irrigation process (Ragheb *et al.*, 2011).

Salt distribution

Figures (8, 9 and 10) (in appendix) indicated that salt distribution under DIS is a reflection of the wetting patterns during irrigation process and subsequently redistribution of soil water content. Wetting pattern under drippers just often an irrigation show that soil salinity varied regarding water quality and treated magnetic force. The low salinity is close to the wetted soil, which is near the dripper and the driest area is at the periphery of the high salt. Also, it is clear to mention that salt distribution under dripper contributed in wetting patterns, which affected directly by water salinity treated or not by magnetic force. The soil salinity of laterals was low concentrated near drippers (the zone of wettest soil); if the dripper placement coincides with plant root. While, if drippers that were an effect from the plant may shift the zone of highest root density away from the dripper and the opposite was true.

There are many factors that could affect root zone soilsalinity under DIS include the salinity of irrigation water, water quality that applied, soil hydraulic properties, the placement of lateral relative to plant rows, and surface or subsurface placement of lateral. Near the dripper, soil salinity will be the least and would reflect irrigation water salinity. However; soil salinity increased with increasing distance from dripper, and hence relatively high value can be obtained near the periphery of the wetted pattern (Hanson *et al.*, 2006). Also, the ability to the treated saline water by magnetic force either 1000 and/or 2000 Gauss has a positive effect on the redistributed salinity under drippers through its ability to dissolve more salts from surface layer and leached it out root zone. This finding is clearly under magnetic force 1000 more than 1000 Gauss, where accumulated salts on the surface layer under irrigation with saline water do not recognize under this investigation. Meanwhile, salt distribution under dripper as affected both water salinity and exposed magnetic force was mainly affected by the amount of irrigation applied, dripper efficiency and water salinity (Aboulila *et al.*, 2013).

Whoever, if the water was the same salinity but the soil salinity differs, the new soil salinity varied considerably with distance from dripper, with a relatively low soil salinity level near the dripper. Salinity levels near the edge of the wetting pattern resulted in an upward flow of deep soil salinity. Higher soil salinity levels near the dripper took place with higher salinity irrigation water **(**Gawad *et al.*, 2005).

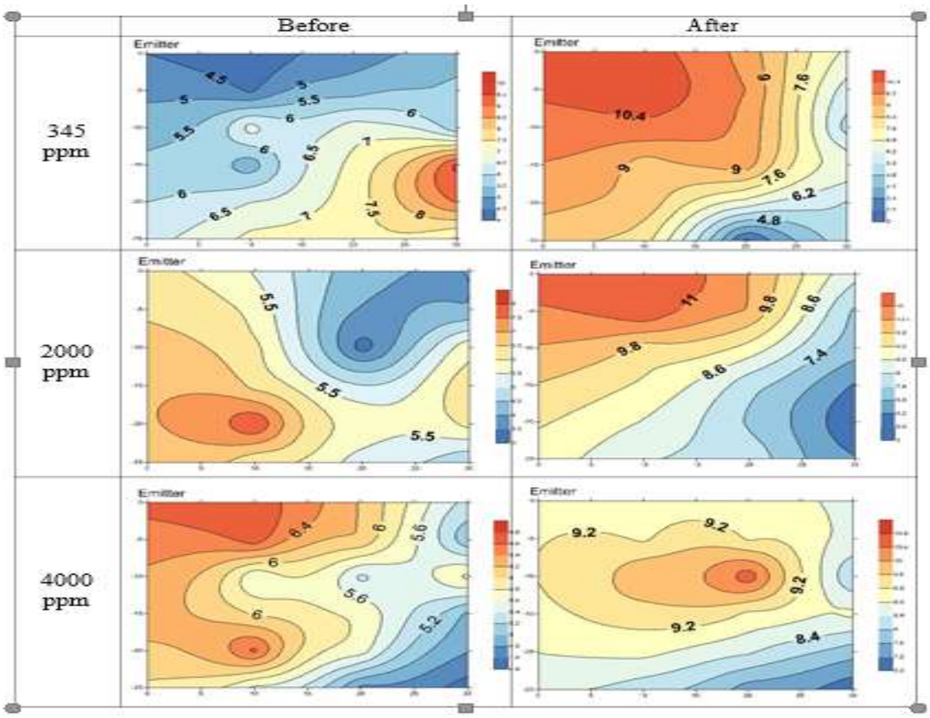

Fig. 5: Water distribution in soil profile as affected by water salinity under magnetic force 0 gauss.

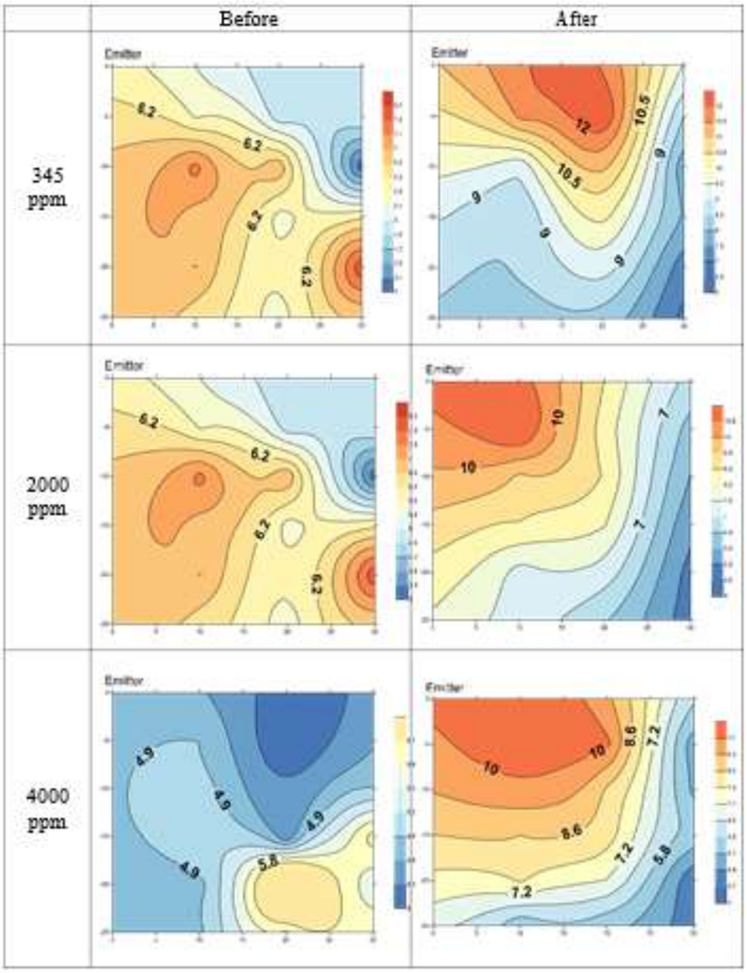

Fig. 6: Water distribution in soil profile as affected by water salinity under magnetic force 1000 gauss.

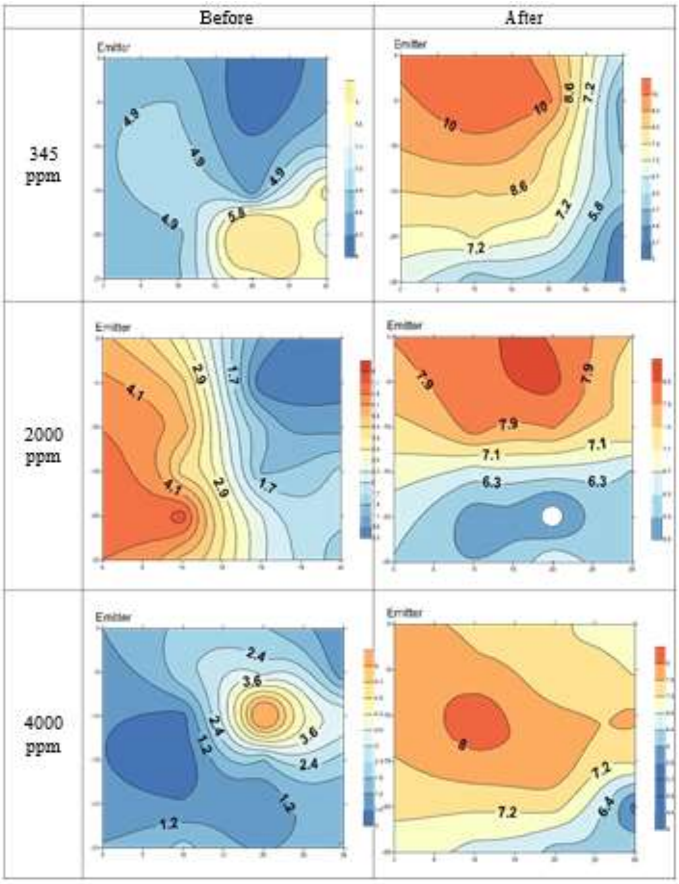

Fig. 7: Water distribution in soil profile as affected by water salinity under magnetic force 2000 gauss.

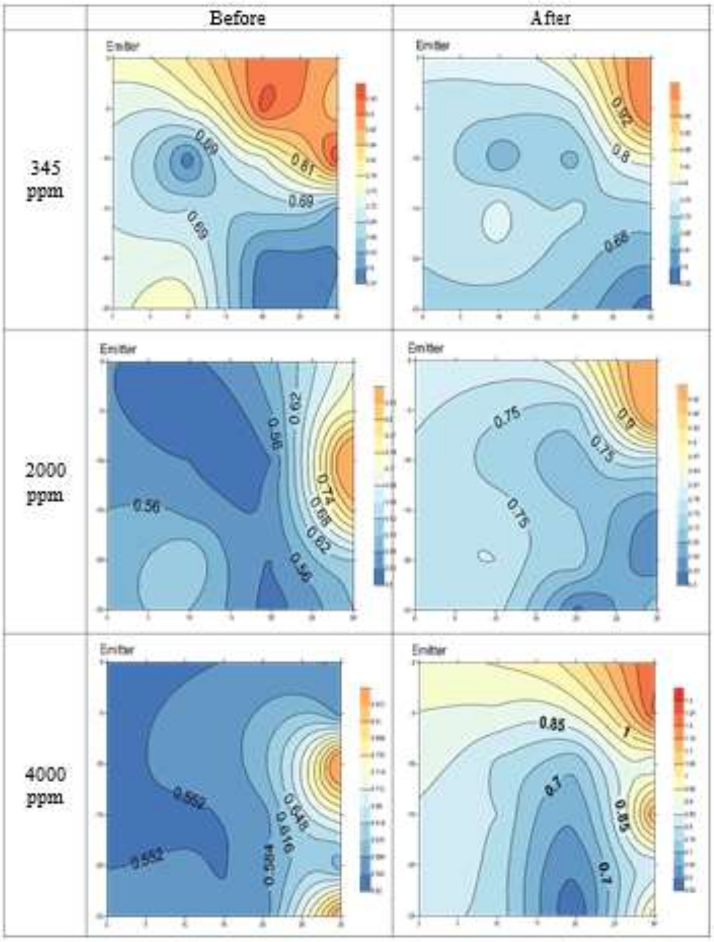

Fig. 8: Salt distribution in soil profile as affected by water salinity under magnetic force 0 gauss.

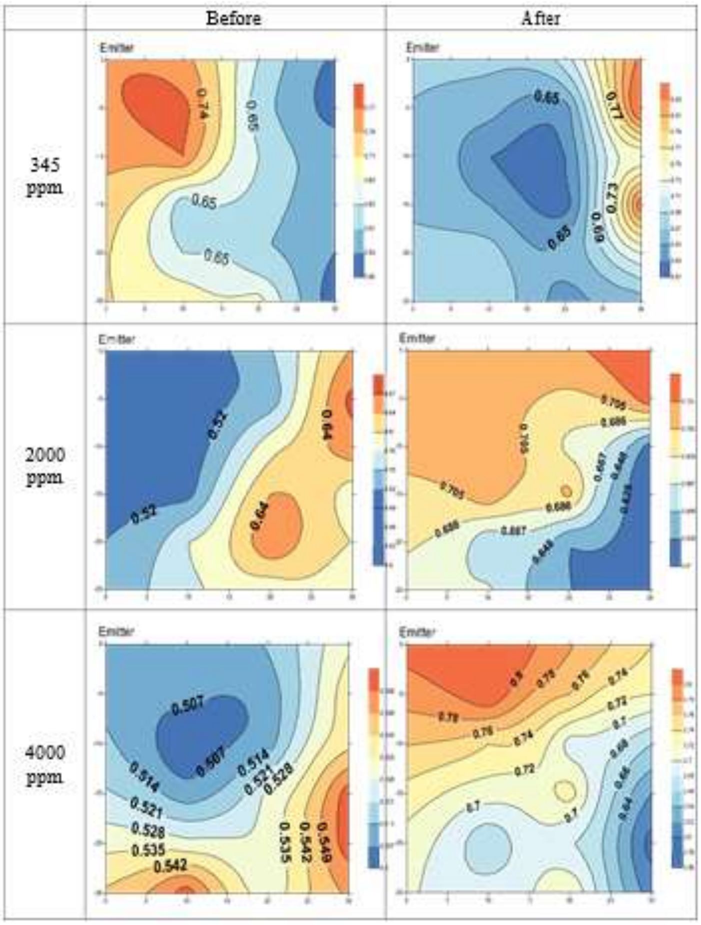

Fig. 9: Salt distribution in soil profile as affected by water salinity under magnetic force 1000 gauss.

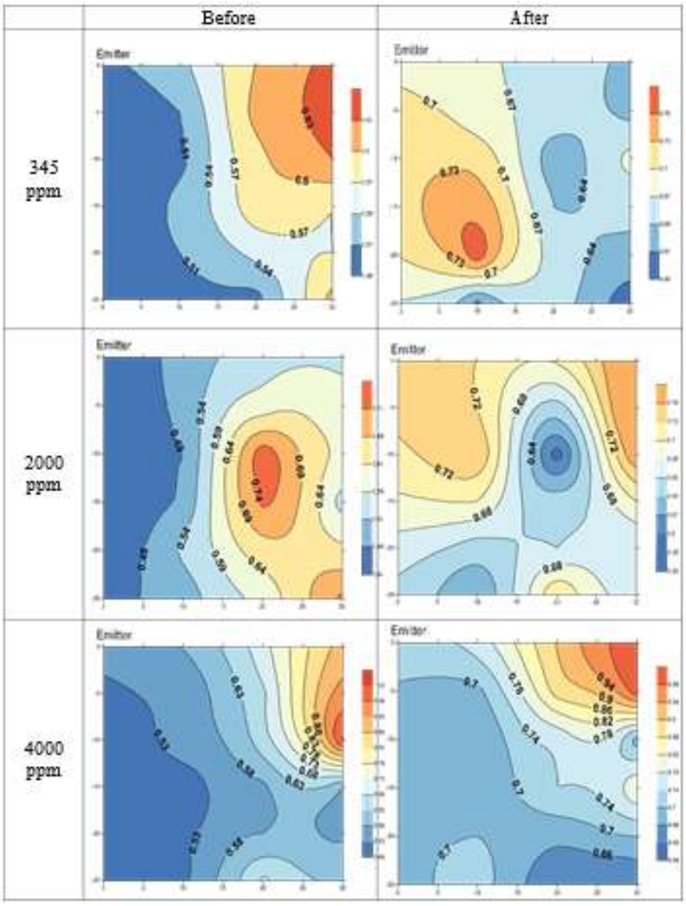

Fig. 10: Salt distribution in soil profile as affected by water salinity under magnetic force 2000 gaus.

Conclusion

The field experiment was a split-plot design. The main plots were magnetic forces treatments. Three magnetic forces treatments were used: zero, 1000 and 2000 Gauss. On the other hand, three salinity treatments (canal water, 345, 2000and 4000 ppm) occupied the sub-plots under turnip crop.

It could be concluded that:

Increasing the dripper flow rate and using saline irrigation water up to 345 ppm, the volume of the wetting front become more in both studied directions. The wetting front of treated saline water (2000 and 4000 ppm) reached 30 cm away from the dripper at the soil surface in a horizontaldirection and became wider than 50cm at the depth of 25 cm underneath the dripper.

After irrigation using the saline irrigation water applied at the same discharge rate the wetting front of low salt water reached 20 cm in the horizontal direction and more than 40 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, where the wetted front that magnetized saline water reached 30 cm in the horizontal direction and more than 25 cm in the vertical direction.

The ability to the treated saline water by magnetic force either 1000 and/or 2000 gauss has a positive effect on the redistributed salinity under drippers through its ability to dissolve more salts from surface layer and leached it out root zone. This finding is clearly under magnetic force 1000 more than 1000 gauss, where accumulated salts on the surface layer under irrigation with saline water do not recognize. Meanwhile, salt distribution under dripper as affected both water salinity and exposed magnetic force was mainly affected by the amount of irrigation applied, dripper efficiency and water salinity

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