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Hydraulic Studies of Drip Irrigation System under Using Low Quality Water Conditions III-Growth and yield parameters and Water crop productivity

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Abstract
Low quality water for irrigation is necessity to dispose safely but we can impose a major environmental constraint to crop production. Both water quality and irrigation system are the main factors that effect on the yield production and quality. Field experiment was carried out in Research and Production Station, National Research Centre, El-Nobaria district, El-Beheara Governorate, Egypt, during 2015/2016 growing season to study the effect of different types of emitter[Non pressure compensating 1emitter (NPC1), Non pressure compensating 2 emitter (NPC2), and Non pressure compensating 3 emitter (NPC3)]under different irrigation water salinity(345, 2000, 4000 ppm) and different operation pressure heads (0.8, 1.0, 1.2, 1.4 bar) on the plant growth characters, yield and water use efficiency (WUE) of turnip crop(*Brassica rapa* *L*)under surface drip irrigation system. The experimental soil is sandy loam in texture.
The obtained results revealed that the highest values of the estimated plant characters were attending at 345 ppm water salinity under all examined emitters. Emitter NPC1 gained the highest yield value (22.28 ton/fed) and NPC3 got the lowest one (19.23 ton/fed), while NPC2 emitter has a superior effect on yield and recorded the highest values which ranged from 27.5; 19.1 ton/fed at 354; 4000 ppm and 12.99, 8.22 kg/m^3, respectively, while Emitter NPC1 gained the highest yield value (22.28 ton/fed) and NPC3 got the lowest one (19.23 ton/fed) with difference 16 %, while NPC2 recorded the highest water use efficiency, WUE (10.8 kg/m^3). WUE for examined emitters NPC2 had a positive effect and recorded increase about 14.5% (NPC1) and 17.4 % (NPC3). The rate of reduction in yield and WUE relative to salinity were 20 and 35 % for irrigation water salinity 2000 and 4000 ppm relative to control one (345 ppm).

Keywords: drip irrigation, emitter type, water salinity, turnip, yield, Water crop productivity.

Introduction
The continuous decrease in water resources in the world in general, and in arid regions such as Egypt in particular has forced farmers to use low quality water and to alter their irrigation practices. The agricultural sectors in Egypt consume more than 80% of the total water income. Therefore, it is necessary to get the maximum yield in agriculture not only by using the available fresh water but also get the maximum profit from the water unit. Furthermore, it is vital to improve the most suitable irrigation method to get the optimum plant yield either for different water quality and crops (Mansour, et al., 2014).
Irrigation water quality can affect not only soil fertility but also mainly to irrigation system performance and reflected on soil physical condition and crop yield. Therefore, knowledge of irrigation water quality is critical to for long-term productivity(Bauder et al. 2004 and Ragab et al., 2008) especially if excess irrigation applications under estimating the suitable irrigation time and quantity, which may cause reduction in yield and salinity (Onest et al. 1995).Most of the new cultivated soils in Egypt are coarse textured, sandy soils, which characterized by low water holding capacities, high infiltration and evaporation rates, low fertility levels and deep percolation losses that induce low water use efficiency9Abdel-Hady, et al., 2011) who mentioned that the drip irrigation system the most suitable system that provides an advantage using saline water with more frequent irrigation to keep a high soil matric and low salt concentration in the root zone.

Wan et al. (2007) concluded on a three year field experiment using saline irrigation water ranging from1.1 to 4.9 dS m^{-1} with a drip irrigation system and exported that water salinity had little effect on tomato yields, but had some effect on seasonal accumulative water use, water use efficiency, and irrigation water use efficiency. However, when sufficient irrigation water is applied to eliminate accumulated salts in soil surface and/or root zone (Hilland Koenig, 1999 and James and Jurinak, 1986). They also added that, if the irrigation system design or operation is such that the application rate just meets the plant requirements and there was no leaching, the expected yield would be less than expected.

Mansoura and Abd El-Hady (2014) stated that it is still debatable whether the reduction in water uptake with increasing salinity is the cause or result of the reduction in growth. However, Al-Omranetal. (2008) reported that salt accumulation in the field was an important factor in reducing the yield. Water crop productivity (WCP), defined as the ratio of the crop yield to seasonal irrigation water (mm^3) applied, including rain. Zeng*et al*. (2009) found that the lower amount of irrigation water applied induced by low irrigation system efficiency was reflected in reduce of wheat yield. These factors indicate that banana is sensitive to even slight variations in soil water content and that irrigation scheduling is critical. Malash et al. (2005; 2008) and Abdelgawad et al. (2005) reported that WCP was higher with drip irrigation over traditional irrigation methods.

The purpose of this study was to investigate the impact type of emitters and irrigation water quality under drip irrigation system on Turnip plant growth characters, yield, water crop productivity water use efficiency in sandy loam soil.

Materials and methods

Field experiments were carried out in the Experimental Farm of Agricultural Production and Research Station, National Research Centre (NRC), El Nubaria Province, Egypt, (latitude 30.8667N, and longitude 30.1667E, and mean altitude 21 m above sea level) to investigate the impact of emitters type (NPC1, NPC2, NPC3) and irrigation water quality (345, 2000, and 4000 ppm) under irrigation system on Turnip crop growth characters, yield, Water crop productivity in sandy loam soil.

Soil texture is sandy textured with values 23, silt; 8 clay after Wild et al., (1985). Some soil characteristics of the experimental soil before cultivation are determined after (Rebecca, 2004) i.e.CaCO3 (2.5 %), OM (0.36%) and both EC (1.80 dSm^{-1}in soil pasteextract); pH (8.12 in soil: water 1:2.5) by Hanna Instruments HI 2550 pH/ORP/EC/TDS/NaCl Benchtop Meter. Also, the soil contained 430 ppm N, 20 ppm P and 43 ppm K.Irrigation water of desired salinity level was prepared by mixing canal water (345 ppm) with underground water (4000 ppm) and stored in plastic tank of 1000 liters capacity. Irrigation process was carried out twice a week regarding to the evapotranspiration (ETo). Uniformity co-efficient was estimated after (Bralts et al., 1987).

Irrigation system and experimental layout

The total area of the experiment was 540 m^2 and divided into nine main plots Layout of the experiment is shown in Fig. 1.The experiment was laid out in factorial RCB design with three replicates.

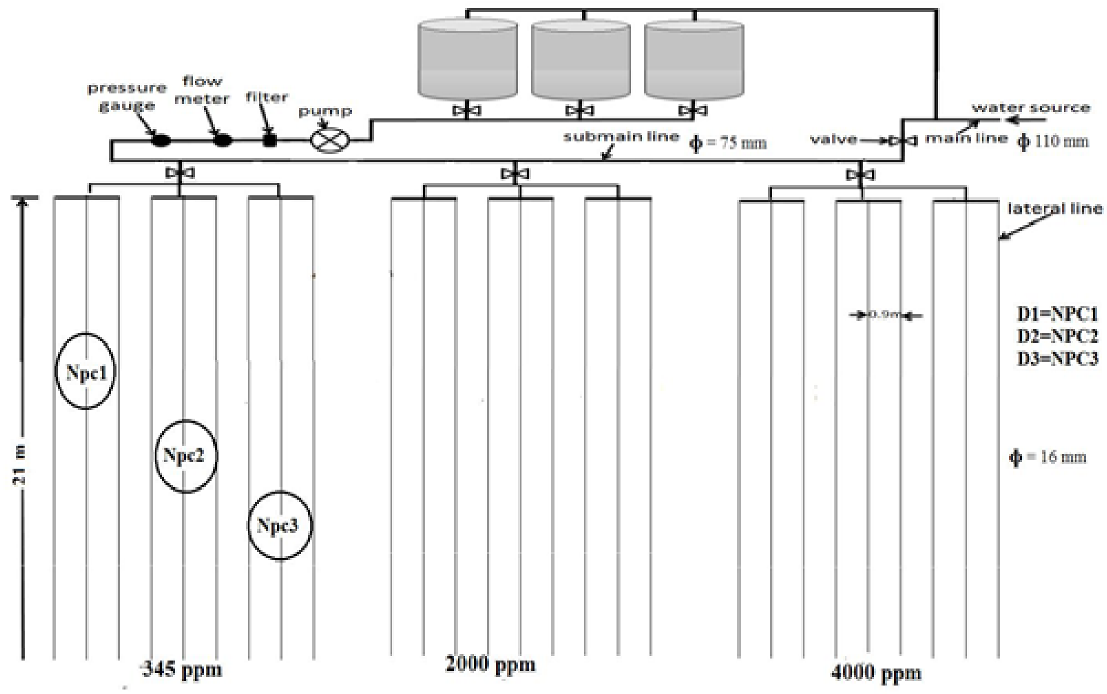

Fig. 1: Layout of the experimental treatments

The system consists of the following components, as presented in Fig. (1)

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

Control head: It is located at the water inlet and consists of:-

- **Pump:** centrifugal electric pump (0.75HP), n ≈ 2900 rpm and discharge 3 m^3/h.
- **Filter:** screen filter 1.5" (one unit), 155 mesh, Max. Flow 7.2m^3 \ h and maximum pressure 150 (PSI).

- **Injection unit:** venture PE of 1", rang of suction capacity 34- 279 l/h.

Pressure gauges, control valves and flow meter.

Main line is PVC pipe, 63 mm diameter (6 bar), connects the control unit to convey the water to sub main lines, which is PVC 32 mm diameter line, delivered from the main line to feed the group of the laterals which represent treatments. In addition to laterals, 16 mm in diameter, PE tubes, with 30 cm apart built in emitters of 4 lph discharge at 1bar operating pressure. Distance between laterals was 0.9 m.

Turnip crop

Turnip (*Brassica rapa L)* seeds were sown manually at 2/11/2015in two rows of each line at 10 cm between plant pits. The plants were harvested at 10/2/2015. The irrigation stopped 10 days before cultivation. The total growth period was 100 days.

All fertilizers were applied just before sowing. Rates of incorporated nutrients were as follows:

100 Kg/fed of calcium super phosphate (15 % P2O5) and 50kg/fed potassium sulphate (50%K2O) were applied during preparation of experimental soil. Ammonium sulphate was applied by 80 kg/fed in three equal doses to the experimental plots as follows: 10, 20 and 30 days after germination. Herbicides and all other agro-technologies were applied according to standard practices.

Plant growth parameters

Turnip plants were taken from each line after 100 days from cultivation. The following measurements were carried out in the collected samples: Growth parameters: Plant length (cm), Weight of leaves / plant (g), fresh weight of root / plant (g), root volume (cm^3), root length (cm) and root diameter (cm). Water use efficiency (WUE) for the crop under all treatments, (kg/m^3), was computed by dividing of total root yield (kg/fed) / total applied water (m^3/fed) throughout the season.

The plant growth parameters were observed weekly throughout the study. For this purpose, five plants in each replicate were randomly selected and tagged for growth monitoring the treatment. The parameters considered were: plant length, leaf length, bio-weight, tuber weight, tuber volume, and tuber diameter were weekly collected on these selected plants and average values were calculated for each replicated.

Statistical analysis

The data were subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design applied after testing the homogeneity of error variances according to the procedure out- lined by Dospekhov (1984). The significant differences (LSD) between treatments were compared with the critical difference at 5% probability level.

Results and discussion

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). 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.

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

Emitter types	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 Emitter type	NPC3	53.02	47.26	680.39	437.00	460.56	7.12
	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**

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.

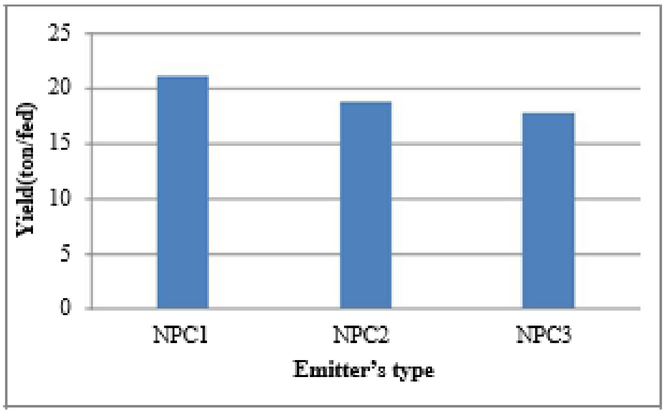

Fig. 2: Effect of different emitter types on growth and yield of turnip crop

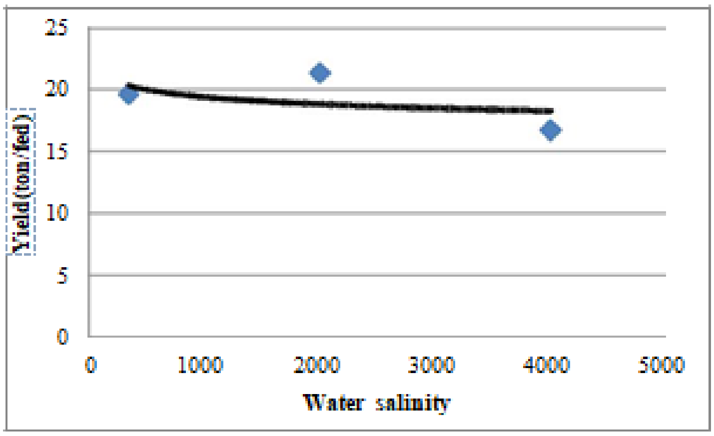

Fig. 3: Effect of different water salinity on growth and yield of turnip crop

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)	$= \frac{1492.5\times(1+0.15)}{0.9} = 1907.1$						

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. Also, Table (3) 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).

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	Water salinity ppm	LR %	Du	Irrigation water consumed (m^3/fed)	Yield (ton/fed)	Water use efficiency (kg/m^3)
NPC1	345	10.0	0.91	1824	23.43 a	12.8 a
	2000	15.0	0.91	1907	21.74 b	11.4 b
	4000	20.0	0.91	1990	18.12 d	9.1 e
NPC2	345	10.0	0.92	1824	20.66 b	11.3 b
	2000	15.0	0.90	1907	19.45 c	10.2 d
	4000	20.0	0.88	1990	16.32 f	8.2 f
NPC3	345	10.0	0.94	1824	19.9 c	10.9 c
	2000	15.0	0.94	1907	17.7 e	9.3 e
	4000	20.0	0.93	1990	15.71 g	7.9 f
Emitter type	LSD 5%			1907	21.10	11.1 a
				1907	18.81	9.9 b
				1907	17.77	9.4 b
Water salinity	LSD 5%			1907	19.63	10.3 b
				1824	21.33	11.7 a
				1990	16.72	8.4 c

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.

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).

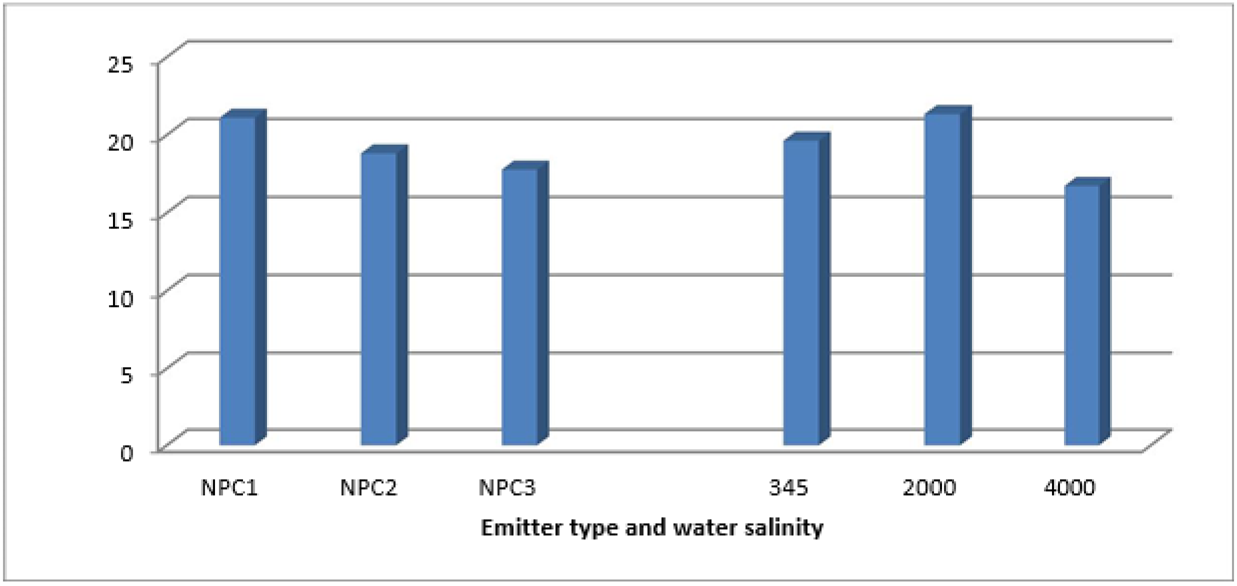

Fig. 4: The effect of water salinity and emitter's type on yield and WUE of turnip crop.

With respect to the water use efficiency (WUE) as affected by both emitters type and water salinity, Table (3) and Figure (4) revealed that emitters NPC1 recorded the higher value followed by the other two investigated types with an a significant difference and there is no significant difference among them.

Figure (4) showed a simple comparison between different water salinity inside and among examined emitters and their effect on WUE where the 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 about 19 % as compared with both examined emitters.

Conclusion
It can be concluded that NPC1 emitter gained the highest yield value (23.43ton/fed) and water use efficiency 14.5 and 17.4 % more than NPC2 and NPC3, respectively. Determined AE% NPC1 emitter, it recorded the highest value (91.74) and NPC1 emitter gained better values of DU when compared with NPC2 and NPC3 under water salinity (345, 2000, and 4000 ppm) and operating pressure (0.8, 1.0, 1.2, and 1.4 bar).

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