HYDRAULIC STUDIES OF DRIP IRRIGATION SYSTEM UNDER USING LOW QUALITY WATER CONDITIONS

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ABSTRACT

Laboratory experiments were carried out at Water Relations and Field Irrigation Dept., National Research Centre (NRC), El-Dokki, Cairo, Egypt to evaluate hydraulic parameters for five emitter types and select the best for applying in field experiments at NRC farm. Then a field experiment was conducted in Research and Production Station, NRC, El-Nobaria, El-Beheara Governorate, Egypt, in 2015/2016 to study the effect of selected emitter's types under different water salinity, on the plant growth characteristics and yield of turnip crop.

Lab experiments were conducted to evaluate hydraulic parameters for five emitter types [On-line emitter NEIN-ETF. Built in (GR), pressure compensating emitters (NEIN-PC), Pressure compensating and Self-flushing emitter (EDEN-PC)and On-line Commercial Katif emitter (KATIF-R-P-201] under water salinity (345, 2000, 4000, 6000. and 8000 ppm) and different operating pressure heads (0.8, 1.0, 1.2, 1.4,1.6, 1.8, and 2 bar). While in field experiment which was carried out to study the effect of some selected emitters [On-line Commercial Katif (CK), Built-in GR (GR), and On-line NEIN ETF, (ETF)] under different water salinity, (2000 and 4000 ppm in addition to the canal water, 345 ppm) on the plant growth characters and yield of turnip (Brassica rapa L).

Results of a lab experiment, in the case of using NPC1, NPC2 and NPC3 at using water salinity 345, 2000 and 4000 ppm were the highest in application efficiency, uniformity coefficient. It could be concluded that emitter types of NPC1, NPC2, and NPC3 under using water salinity 345, 2000, and 4000 ppm were the best and could be recommended to apply in the field research work.

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According to field experiment, data 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/m³, 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 (10.77 kg/m³). 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: *Hydraulic, drip irrigation, Emitter types, water salinity, turnip, water use efficiency.*

INTRODUCTION

The efficiency of the irrigation system is the most important factors in the design and management of micro-irrigation system, so the increase in crop production is the vital goal and the big investment on farms and smallholdings alike. Since the emitter is the most critical component of the drip irrigation system, which is designed to discharge water consistently to plant root zone. The uniformity in flow rate from drippers is affected due to pressure variation, manufacturing variation, the temperature variation of the flowing water and dripper clogging. Drip irrigation has many benefits, but one of the most serious problems in the system is dripper clogging. It is attributed to a number of factors and is classified into physical, chemical and biological properties **(Shinde et al., 2012)**. Salinity could be one of the main causes of emitter clogging in a drip irrigation system, which builds up either from irrigation water and/or fertigation process. Emitter clogging depends on upon its water discharge capacity, where the emitters with large nominal discharge, self-flushing, and pressure compensating features recorded less flow rate reduction than less nominal discharge emitters **(Hezarjaribi et al., 2008; Aali et al., 2009)**. Choosing emitters with higher discharge

rates might be important due to the highly clogging percentage, which observed in the smaller discharge rate emitter than higher discharge one (**Bozkurt and Ozekici, 2006**). Water quality is important when the water contains high amounts of soluble cations, especially with SO_4^- and/or HCO_3^- owing to the high risk of emitter clogging and consequently system performance (**Sanij** *et al.,* **2001; Ribeiro** *et al.,* **2004**).

Emitter clogging may be due their extreme small passages of water and low flow rate (**Ozekici, 1998**). **Kulkarni (2005)** added that more clogging emitters were found at the end of the drip laterals than at the beginning probably due pressure head loss. **Hebbar** *et al.* **(2004)** found that normal fertilizers generally tend to clog the emitters causing an uneven distribution of fertilizers. **Phocaides (2000)** carried a study on the effect of different fertigation practices on clogging of inline emitters using Samandag region well water in Turkey. Their data showed that different fertilizer treatments have a significant effect on emitter clogging. Fertilizers containing both Ca^{2+} and SO_4^- caused higher clogging compared with the others. **Mansour** *et al.* **(2013)** said that as water flow in irrigation system slows down and/ or the chemical back- ground of the water changes, chemical precipitates and/or microbial flocks and slimes begin to form and grow, thus emitters clogging occur.

Uniform application (UA) of water in agriculture has a major impact on crop production and net farm income, where water is saved when irrigation uniformity is improved. Ideally, all emitters in micro irrigation should deliver equal quantity at irrigation process (**Phocaides, 2000**). The uniformity in flow rate from emitters is affected by pressure variation, manufacturing variation, the temperature of the flowing water and emitter clogging (**Reinders** *et al.,* **2005; Mansour** *et al.,* **2015**). A number of studies on the drip irrigation system with the use of saline or sodic water for irrigation were done. The water, having a high pH or EC was responsible for decrease emitter efficiency. A non-uniform distribution not only can deprive portions of the crop of needed water, but, furthermore, can over irrigate portions of a field, leading to water-logging, plant injury, salinization, and transport of chemicals into the ground water (**Amor et al., 2014**). Distribution uniformity (DU) is

defined as a measure of the uniformity with which irrigation water is distributed to different areas in a field.

Koegelenberg *et al.* **(1999)** studied the uniformity of manufacture of emitters; small manufacturing differences between emitters may cause significant variations in discharge. The coefficient of manufacturing variation (CV) is used as a measure of the anticipated variation in discharge for a sample of new emitters (**Uys, 2000; Van Niekerk, 2006**). They added that CV is a very useful parameter with rather consistent physical significance because the discharge rate for emitters at a given pressure is essentially normally distributed. The physical significance of CV is derived from the classic bell-shaped normal distribution curve in which:

• Essentially all the observed discharge rates fall within (1 ±3 CV) of the average discharge rate;

• Approximately 95% of the discharge rates fall within (1 ±2 CV) of the average discharge rate;

• Approximately 68% of the discharge rates fall within (1 ±1 CV) of the average discharge rate; and they state that the average of the lowest quarter of the discharge rates is approximately equal to (1 − 1.27 CV) to the average discharge rate.

Wan *et al.* **(2007)** found in three years trails using saline irrigation water (1.1 to 4.9 dS m^{-1}) under drip irrigation system and exported that water salinity had little effect on tomato yields, but had some effect on the 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 (**Hill and Koenig, 1999**). The aim of this research is to investigate the hydraulic evaluation for five emitter's types and the best three types, applied in the field experiments at NRC farm. They study the influence of different water salinity on the performance of selected emitters, Study the influence of various operation pressures on the performance of selected emitters, Evaluate the effect of water salinity and emitter type on the crop yield, select the emitter which achieves better results and determine the amount of irrigation water, which can be saved using the accurate emitter.

MATERIAL AND METHODS

Laboratory experiments were carried out at Water Relations and Field Irrigation Department, National Research Centre (NRC), El-Dokki, Cairo, Egypt to evaluate hydraulic parameters for five emitter types and select the best for applying in field experiments at NRC farm. Then a field experiment was conducted in Research and Production Station, NRC, El-Nobaria, El-Beheara Governorate, Egypt, in 2015/2016 to study the effect of selected emitters types under different water salinity, on the plant growth characteristics and yield of turnip (*Brassica rapa* L).

Soil and irrigation water

Lab experiment was carried out at Water Relations and Field Irrigation Department, National Research Centre (NRC), El-Dokki, Cairo, Egypt to evaluate hydraulic parameters for five emitter's types and select the best for applying in field experiments at NRC farm.

A field experiment was carried out in the Experimental Farm of Agricultural Production and Research Station, National Research Centre (NRC), El Nubaria Province, Egypt, sandy soil (latitude 30.8667N, and longitude 30.1667E, and mean altitude 21 m above sea level). The soil type of this site is sandy loam textured. Some soil chemical properties were measured in the laboratory of Soil Department. NRC as follows: Soil pH and EC were measured in 1:1 (soil: water suspension) and in soil paste extract, respectively. The total available water within the soil depth and the mean bulk density varies as shown in Table (1).

Table (1): Soil properties of the experimental site.

Depth (cm)	pH 1:2.5	EC, dS/m	C. Sand	F. Sand	Silt	Clay	Texture Class	FC	PWP	AW	BD (g/cm³)	TP (%)
			Particle Size distribution, %					(% on weight basis)				
0-15	8.3	0.35	13.7	75.1	7.4	3.8	Sandy	13.15	5.23	7.9	1.53	40.38
15-30	8.2	0.36	13.5	75.6	7.3	3.6	Sandy	12.0	5.35	6.5	1.47	39.62
30-45	8.3	0.34	13.8	75.3	7.4	3.5	Sandy	13.02	5.7	7.0	1.48	38.11
45-60	8.4	0.73	13.9	74.6	7.6	3.9	Sandy	14.1	5.92	6.4	1.47	37.36

FC: Field capacity; PWP: Permanent wilting point; AW: Available water; B.D: Bulk density, and TP: Total Porosity.

Chemical properties of irrigation water

Chemical analysis of irrigation water was measured with using the standard methods and shown in Table (2). All the measured chemical parameters describe the status of the irrigation water and it can be used normally in irrigation.

Table (2): Some chemical properties of irrigation water.

Water sample	pH	EC dS/m	EC ppm	Soluble anions and cations (meq/l)								SAR
				Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^-	HCO_3^-	SO_4^-	Cl^-	
Canal 345ppm	7.34	0.845	474.88	2.01	1.68	2.88	0.85	0.0	0.47	3.01	3.94	2.12
Well 4321ppm	7.53	6.501	4160.64	21.23	18.28	23.35	2.15	0.0	0.53	28.24	36.24	5.25
Mix 2000ppm	7.46	3.126	2000.64	9.65	7.85	13.41	0.35	0.0	0.46	9.54	21.26	4.53

EC: Electrical conductive; SAR: Sodium absorption ratio.

Climatic data

The average climatic data during the evaluation months of growing season were obtained from Central Laboratory for Agricultural Climate (CLAC). Detailed daily values of weather data during the growing season are presented in Table (3).

Table (3): Average climatic data at the experimental site during the months of evaluation.

| Month	T_{max} (°C)	T_{min} (°C)	RH_{mean} (%)	N (hours)	u_2 (m s^{-1})	P (mm)
November	24.4	13.2	61.3	10.6	2.22	17
Desember	19.9	9.1	45.2	10.2	1.75	22
January	18.3	7.6	48.2	10.4	1.37	18
February	19.3	8.3	52.3	11.1	1.48	15

T_{max}: Maximum value of temperature; T_{min}:Minimum value of temperature; RH_{mean}: Mean value of relative humidity; u_2:Wind speed;; N:Maximum possible sunshine duration; and P:Precipitation.

Irrigation system

a- Lab experiment

The lab study used a laboratory-scale apparatus fitted with two laterals of PVC drip tubing, each 15 m in length. Each lateral contains 50 emitters

with a space of 30 cm. Water was supplied to the laterals from a Polyethylene, 500L (0.5 m³) supply tank using a 373-watt (0.5hp), high-pressure pump. Additionally, a flow meter was installed to record the total volume of water supplied to the system. The pressure in the laterals was regulated by a two bar regulator installed after the pump. One-liter measuring cylinders with 10 ml divisions were used to collect the water from the emitters as shown in Figure (1).
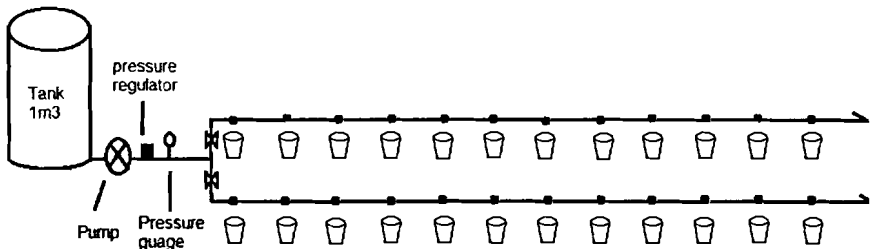
Fig. (1): Lab experiment layout.

b- Field experiment

For the field experiment, the total area of the experiment was 540 m² and divided into nine main plots as shown in Figure (2). The system consists of the following components:

a. Tank:

Three Polyethylenes, 1 m³ tanks with a float inside was connected to the control head. The tanks are being filled with water through PVC pipe, 63 mm diameter and 6 bar operating pressure, derived from the main line of the farm.

b. Pumping unit:

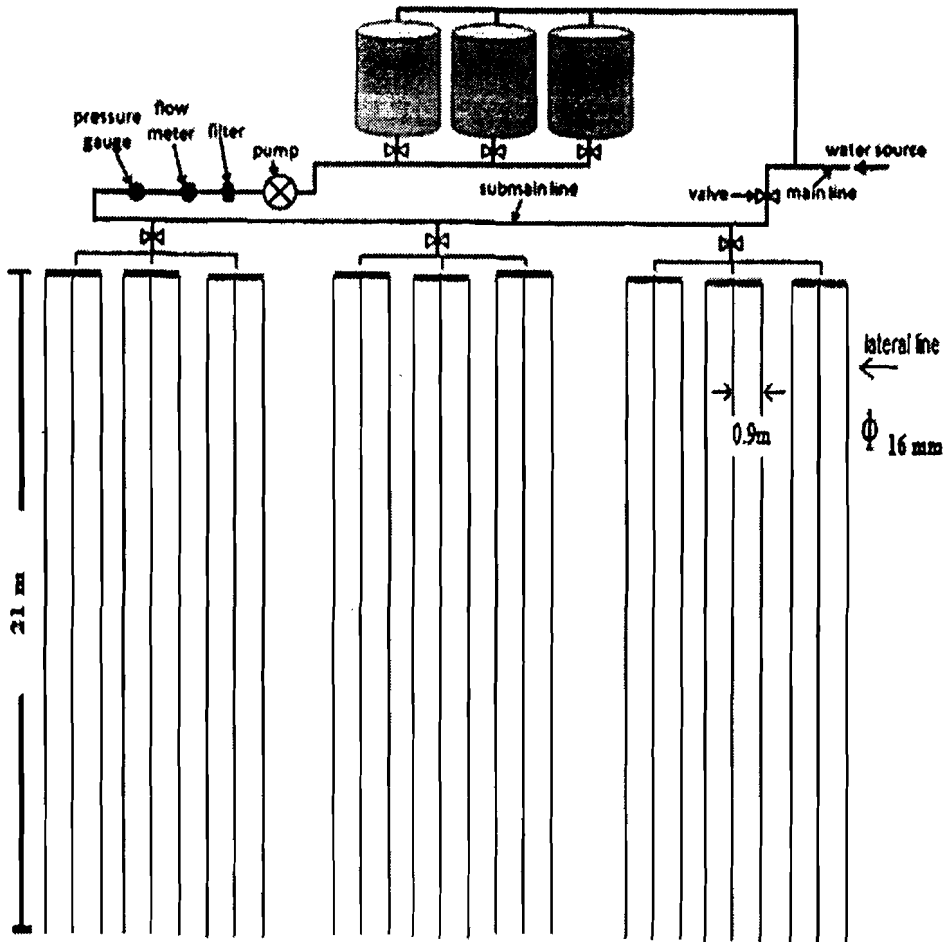| Pump	Motor
Type: 4AMP180L4MY5.	Type: NT65-400/390, 4IB-W2, 4522356/15.
RPM: 1450 – 50 HZ.	Power: 22 KW.
Pressure: 5.5 bar.	Voltage: 380-680 V- 3 PH.
Flow rate: 70m³/h	Efficiency: 90%.
Weight: 55 kg.	

Fig. (2): The irrigation system components.

c. **Control head:**

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 150 (PSI).
- Spring brass none return valve: 2inches.

- pressure gauges: 0-10 bar
- Control valves: UPVC ball valve, 2-inch diameter and 6 bar operating pressure.
- Flow meter.

d. Mainline:

PVC pipe of 110 mm diameter connects the control unit for conveying the water to sub-main lines.
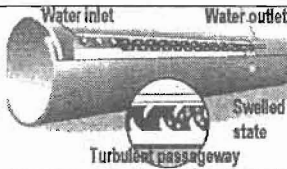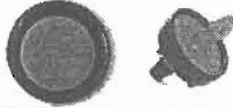
e. Sub main lines:

PVC 75 mm diameter line derived from the main line to feed the manifold lines.

f. Lateral lines:

PVC 63 mm diameter line connects to the sub-main lines to feed the group of risers.

g. **Emitters:** Five types of emitters were used in this experiment as shown in Table (4).

Table (4): Types of examined emitters' nominal characteristics.

Emitter model	Emitter type	Diameter
NEIN-ETF	NPC1 Online	
GR	NPC2 Built-in	
NEIN ENEIN-PC	PC Online	
EDEN NEIN-PC	PCS Online	
KATIF Rivulis Plastro 201	NPC3 Online	

PC: Pressure compensating, NPC: Non pressure compensating, PCS: Pressure compensating and Self-flushing.

Turnip crop

Turnip (*BrassicarapaL*) seeds were sown manually at 2/11/2015in two rows of each line at 10 cm between plant pits. The plants were harvested at 10/2/2015with total growth period was 100 days. The irrigation stopped 5 days before harvesting. Standard crop coefficients (Kc) of the four growth stages (initial stage, crop development stage, mid-season stage, and late season stage) for turnip crop according to single-Kc are tabulated in Tables (5).

Turnip plants were taken from each line after 100 days from cultivation. Water Productivity: Water use efficiency (WUE) or Water Productivity (WP) 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.

Table (5): 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 days)		Mid- season (35 days)		Late season (15 days)	
Kc	0.5	0.8		1.10		0.6	

All fertilizers were applied just before sowing in recommended doses from calcium super phosphate (15 % P$_2$O5) and potassium sulphate (50%K$_2$O) were applied during the preparation of the 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.

Calculation of water requirements

Data of water requirements for turnip crop were calculated. According to the climatic data recorded at the nearest meteorological station, the average metrological parameters needed for the calculation were recorded using CROPWAT computer model and applying Penman-monteith equation and K$_c$ values presented in the program and also illustrated in **Allen et al. (1998).** Crop evapotranspiration (Et$_c$) was calculated according to the following formula:

$$ET_c = K_c . ET_o \quad \dots\dots\dots\dots\dots (1)$$

Where

ET_c = crop evapotranspiration in mm / day.

ET_o = reference evapotranspiration in mm / day.

K_c = crop coefficient.

Emitters discharge

A numerical method to measure the desirability of pressure, flow characteristics for a given emitter device is based on a flow rate vs. pressure curve (Q-H) fitted to an equation of the following form:

$$Q = kH^x \dots\dots\dots\dots\dots\dots\dots (2)$$

Where: Q is the emitter flow rate, m³/h; K is the constant depending on emitter type; H is the operation, m; and x is the exponent characteristics of emitters, unit less.

Exponent x is an indication of the flow regime and emitter type. It is an indirect measure of the sensitivity of flow rate to the change in pressure. The value of x typically ranges between (0 - 1.0), where a lower value indicates a lower sensitivity and a higher value indicates a higher sensitivity. For PC emitters the value should be less than 0.1 and should approach 0. For NPC emitters, it should approach 0.5 **(Cuenca, 1989)**.

As shown in Table (6), emitters with exponents less than 0.5 are entitled to be called pressure compensating, to different extents **(CIT, 2002)**.

Table (6): Emitter exponent values for various flow regimes and emitters (Adapted from IA, 2002).

Flow regime	Exponent x	Emitter type
Variable flow path	>0.1	Fully pressure compensating
	0.1	⬍
	0.2	
	0.3	Partially pressure compensating
Vertical flow	0.4	
Fully turbulent flow	0.5	Non-pressure compensating
Mostly turbulent flow	0.6	⬍
	0.7	
Mostly laminar flow	0.8	Fully non-pressure compensating
	0.9	
Fully laminar flow	1.0	

Emitters Clogging

To estimate the emitter flow rate cans and a stopwatch was used. Nine emitters from each lateral had been chosen to be evaluated by calculating their clogging ratio at the beginning and at the end of the growing season for two seasons. Three emitters at the beginning, three at middle and threat the end of the lateral were tested for flow rate. Clogging ratio was calculated using the following equations (**El-Berry** *et al.,* **2003**):

$$E = qu / qn * 100 \quad \text{............................. (3)}$$

$$CR = (1 - E) \, 100 \quad \text{............................. (4)}$$

Where:

E = the emitter discharge efficiency (%)

qu = emitter discharge, at the end of the growing season (L/h)

qn = emitter discharge, at the beginning of the growing season (L/h)

CR = the emitter clogging ratio (%)

The pressure influence on emitter flow rate can be presented in two ways, either directly as the average of emitter flow rate or as a percentage of flow rate change that occurs at the actual operating pressure and pressure of 1 bar with the same water temperature, divided by the flow rate at a pressure of 1 bar according to (**Keller and Karmeli, 1974**) as follows:

$$q \, var = \frac{qmax - qmin}{qmax} \, X \, 100 \text{........................ (5)}$$

Where;

q_{var}: the emitter flow variation,

q_{max}: the maximum emitter flow along the lateral line, l/h, and

q_{min}: the minimum emitter flow along the lateral line, l/h.

Manufacturing coefficient of variation

The coefficient of variation (CV) is defined as the ratio of standard deviations of the discharges (**Madramootto, 1988**). In the lateral design, emitter flow variation is used as a design criterion. The emitter flow variation comprises hydraulic variation and due to manufacturing variation among the emitters. The latter depends on the quality control in production. The unit to unit variation in the emitter flow was expressed by the following relationship:

$$CV = \frac{s}{qa} \times 100 \ldots\ldots\ldots\ldots (6)$$

Where:

CV: manufacturing coefficient of variation,

S: sample standard deviation and

q: average emission rate of the sample.

Table (7): Micro-irrigation system uniformity classification based on the coefficient of variation.

Emitter type			
Point-source		Line source	
C_v range	Classification	C_v range	Classification
< 0.05	Excellent	< 0.10	Good
0.05 - 0.07	Average	0.10 – 0.20	Average
0.07 - 0.11	Marginal	>0.20	Marginal to Unacceptable
0.11 – 0.15	Poor		
>0.15	Unacceptable		

*Adopted from ASABE Standards EP405.1, 2008R

The standard deviation of emitter flow rate, Sq, **(ASABE, 2008R)** can be written as:

$$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(qi - qa)^2} \ldots\ldots\ldots\ldots (7)$$

The coefficient of manufacture variable measures the variation in flow rate for a given emitter model at a normal operation pressure ranging from 0.2 to 2.0 bar and a water temperature of (20-23°C). The emitter manufacture's coefficient of variation "CV" is one of the statical terms, which can be used to show the drip irrigation system uniformly.

Emission uniformity

Keller and Karmeli (1974) revealed that a statical uniformity could be used to indicate performance for emitters. Values were calculated according to the following equation:

$$EU = \frac{qn}{qa} \times 100 \ldots\ldots\ldots\ldots (8)$$

Where EU: the emission uniformity, %, q_n = the average of lowest 1/4 of the emitter flow rate, in l/h, and q_a: the average of all emitter flow rates.

Lab experiment was carried out to evaluate hydraulic parameters for five emitter types and select the best for applying in field experiments at NRC farm. Factors under study were water salinity (345, 2000, 4000, 6000; 8000 ppm) and emitter's types (NPC1, NPC2, NPC3, PC; PCS) under different operation pressure head (0.8, 1.0, 1.2, 1.4, 1.6, 1.8; 2 bar).

Emitter discharge was measured (volumetrically and triplicated) over a range of seven pressures (0.8, 1.0, 1.2, 1.4, 1.6, 1.8, and 2 bar) to determine the manufacturing variation of each type. A stopwatch was used to measure the flow times. The water volumes were collected in the graduated cylinders and manually read and recorded.

A field experiment was carried out to study the effect of selected emitters types (NPC1, NPC2, and NPC3) under different water salinity, (2000 and 4000 ppm in addition to the canal water, 345 ppm) on the plant growth characters and yield of turnip (Brassica rapa L).

Irrigation water of desired salinity level was prepared by mixing canal water (345 ppm) with underground water (4321 ppm) and stored in a plastic tank of 1000 liters capacity. Irrigation process was carried out twice a week regarding the evapotranspiration (ETo) as well as leaching requirements that considered about 10 % in all treatments.

The total area of the experiment was 540 m^2 and divided into nine main plots as shown in Figure (3).
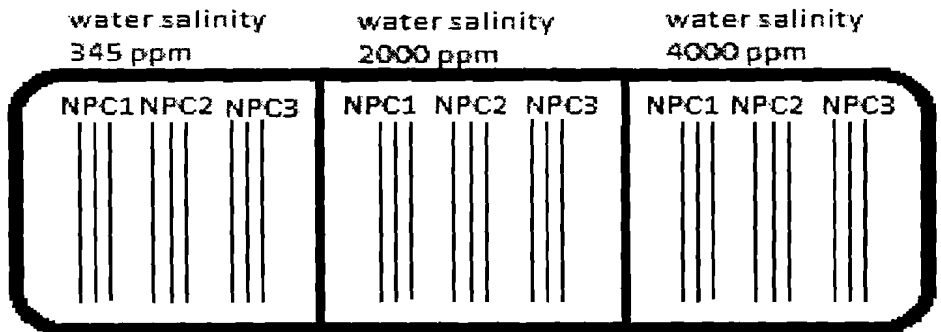

Fig. (3): layout of the experimental layout.

Statistical analysis

The data were subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design, factorial, 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 the 5% probability level.

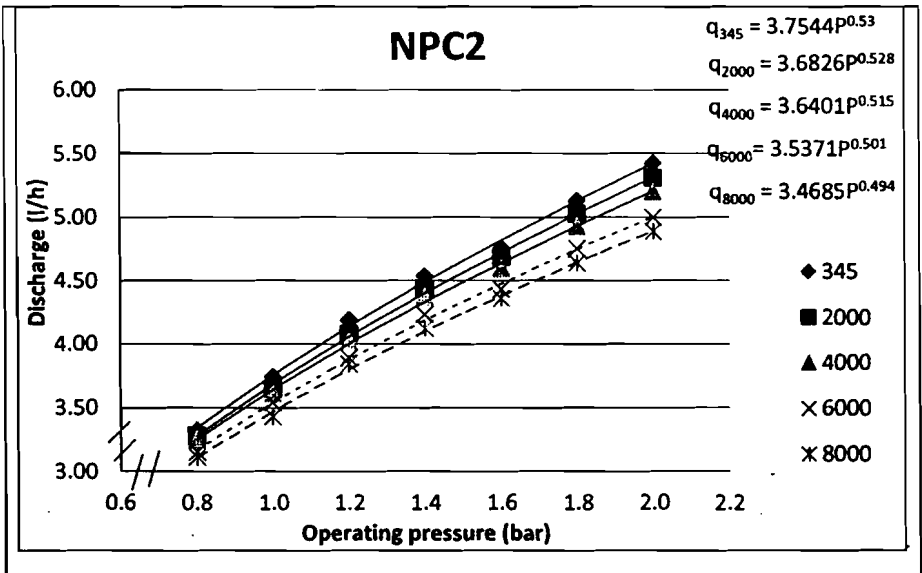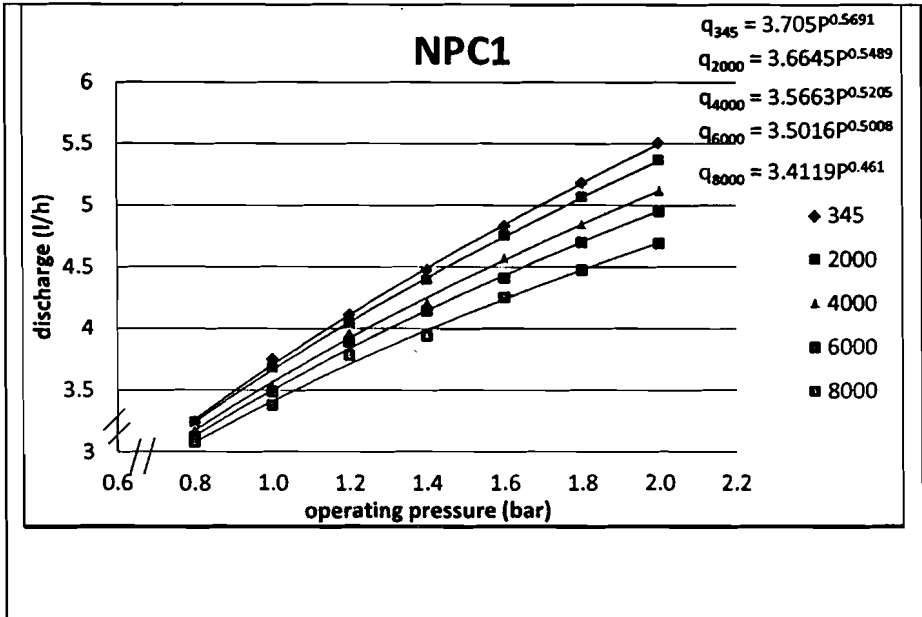## RESULTS AND DISCUSSION

Calculation of water requirements

Table (8) Water requirement of the turnip crop:

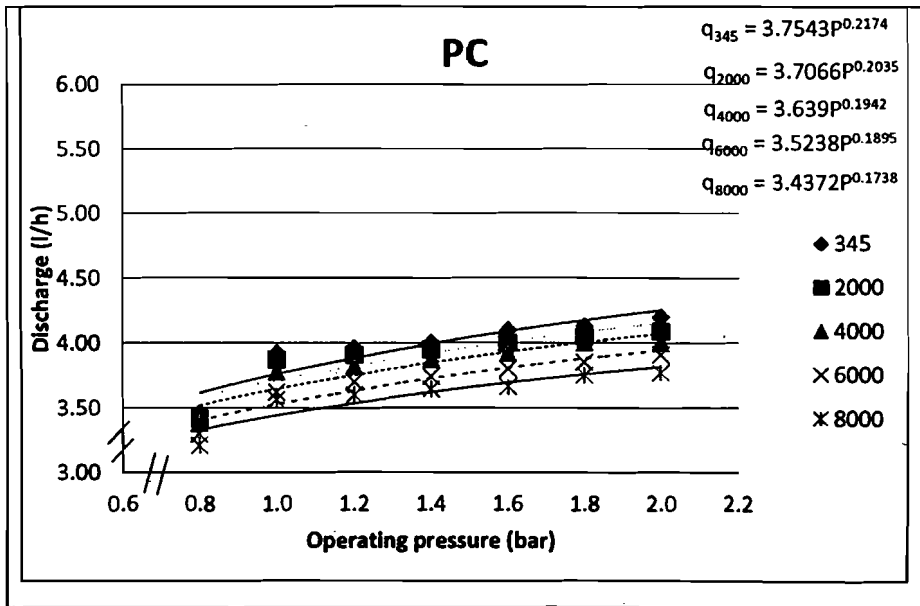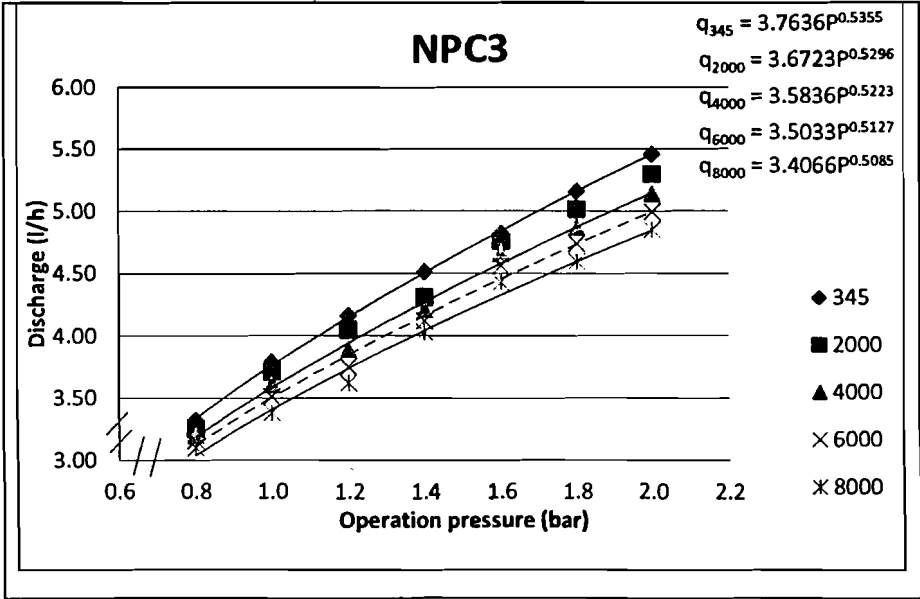| Month	Nov.		Dec.			Jan.	Feb.
ETo (mm/day)	2.88		2.49			1.65	2.54
Stage	20	8	22	9	26	5	10
	Initial stage (20 days)	Development stage (30 days)		Mid- season (35 days)		Late season (15 days)	
Kc	0.5	0.8		1.10		0.6	
ETc(mm/day)	1.44	2.30	1.99	2.74	1.82	0.99	1.52
ETcm^3 /day/Fed	6.1	9.7	8.4	11.5	7.6	4.2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

Calibration of emitters:

It is known that in a drip irrigation system is a positive relationship between the operating pressure and the emitter flow rate. This relationship may be affected by some changes in the physical properties of water; one of these changes is to increase the proportion of salt, which exists in low-quality water. Figure (4) illustrates the relation between the emitter flow rates with water salinity and operation pressure.

Regarding the effect of operation pressure on the flow rate of the different studied emitters NPC1,NPC2, PC, PCS, and NPC3), one can notice that increasing operation pressure associated with the increasing emitters flow rate. Also, the highest and lowest flow rate values as affected by increasing operating pressure for the examined emitters were attained at 1.6 and 0.8 bar, respectively as shown in Figure (4).

NPC1

$q_{345} = 3.705P^{0.5691}$
$q_{2000} = 3.6645P^{0.5489}$
$q_{4000} = 3.5663P^{0.5205}$
$q_{6000} = 3.5016P^{0.5008}$
$q_{8000} = 3.4119P^{0.461}$

♦ 345
■ 2000
▲ 4000
▣ 6000
▢ 8000

discharge (l/h)
operating pressure (bar)

NPC2

$q_{345} = 3.7544P^{0.53}$
$q_{2000} = 3.6826P^{0.528}$
$q_{4000} = 3.6401P^{0.515}$
$q_{6000} = 3.5371P^{0.501}$
$q_{8000} = 3.4685P^{0.494}$

♦ 345
■ 2000
▲ 4000
✕ 6000
✳ 8000

Discharge (l/h)
Operating pressure (bar)

NPC3

$q_{345} = 3.7636P^{0.5355}$
$q_{2000} = 3.6723P^{0.5296}$
$q_{4000} = 3.5836P^{0.5223}$
$q_{6000} = 3.5033P^{0.5127}$
$q_{8000} = 3.4066P^{0.5085}$

◆ 345
■ 2000
▲ 4000
✕ 6000
✖ 8000

Discharge (l/h)

Operation pressure (bar)

PC

$q_{345} = 3.7543P^{0.2174}$
$q_{2000} = 3.7066P^{0.2035}$
$q_{4000} = 3.639P^{0.1942}$
$q_{6000} = 3.5238P^{0.1895}$
$q_{8000} = 3.4372P^{0.1738}$

◆ 345
■ 2000
▲ 4000
✕ 6000
✖ 8000

Discharge (l/h)

Operating pressure (bar)

Fig. (4): Effect of water salinity and emitter flow rate.

Meanwhile, the lowest flow rate value (3.27 l/h) was obtained from PCS at 0.8 bar and the highest value was recorded after operation pressure 1.6 (4.26 l/h) from emitter NPC1. Additionally, PCS followed by NPC3 recorded the lowest flow rate3.61 and 3.99 l/h, respectively. And the other tested emitters could be arranged in descending order relative to the flow rate NPC1> PC> PCS>NPC3>NPC2. Also, it is worth to mention that the rate of increase flow rate as affected by operation pressure were 4, 9, 14 – 3, 5, 8 and 3, 5, 9 % in same sequences, if we compare the emitter flow rate at 1, 2; 1.4 bar comparing with 0.8 bar.

With respect to the water salinity and its effect on the flow rate of the examined emitters, Figure (4) illustrated that PCS and PC were the worthy ones that dramatically decreases their flow rate with increasing water salinity. From the other side, NPC1and NPC3 were the most suitable and moderately affected by water salinity followed by NPC2.

The maximum and minimum numbers of the flow rate of the tested emitters were obtained after canal water and 8000 ppm saline water. In addition, the highest flow rate value relative to water salinity could name as NPC1 (canal), NPC2 (2000 ppm), NPC1 (4000 to 8000 ppm water salinity). From the abovementioned, it is clear to point out that emitter

named NPC1 followed by NPC2 and lastly NPC3 were not affected strongly by increasing water salinity. Our data was in agreement with those obtained by **Almajeed and Alabas (2013),** who stated that the main problem is the drop in pressures and discharges distribution in the network resulting from the amount of pressure losses between the head of the lateral as compared with that in the end of the lateral, which affects the discharge distribution of emitters and uniformity.

Table (9): The effect of different emitter types and saline water on clogging percent.

Water Salinity	Clogging ratio (%)				
	NPC1	**NPC2**	**PC**	**PCS**	**NPC3**
345	9.58	8.36	20.45	21.36	9.33
2000	10.47	10.75	24.36	22.54	10.25
4000	11.23	11.37	26.41	24.52	11.46
6000	20.54	21.64	28.36	27.8	21.36
8000	22.65	22.35	29.56	26.35	23.75

In this research work has been the use of water of varying salinity to test five types of emitters under five different operating pressure and emitter hydraulically tests measured the disposal of all cases, and also calculate the coefficient of variation and uniformity coefficient of each case. It could conclude the regression equations after plotting the primary data on log/log paper to get power equation that represents the relation between flow rate and operation pressure for each tested emitter.

According to the data obtained by the relationship between pressure head (bar) and flow rate (l/hr), one can notice that emitter types of NPC1, NPC2, and NPC3 at using water salinity 345, 2000, and 4000 ppm were the best for using and could be recommended to use them the field research work.

**Uniformity and coefficient of variation of testing emitter types**

Table (10) and Figure (5) illustrate the effect of emitter type on application efficiency (AE %), distribution uniformity (DU) and

coefficient of variation (CV) under (1.0 bar) as a nominal pressure head, one can notice that for AE and DU, the ranked of emitter type were NPC3>NPC2>NPC1>PCS>PC. According to application efficiency, there are significant differences between all values of emitter types. But in respect to distribution uniformity, there are significant between NPC3 and other emitter types, and no significant differences between NPC1 and NPC2 types.

Table (10): The effect of emitter type on Application efficiency, distribution uniformity and coefficient of variation under (1.0 bar) as a nominal pressure head.

Emitter type	Application efficiency (AE) %	Distribution uniformity (DU)	Coefficient of variation (CV) %
NPC1	93.94b	0.932b	0.035
NPC2	94.22c	0.943bc	0.10
PC	82.54e	0.836d	0.11
PCS	82.34d	0.831e	0.09
NPC3	94.74a	0.938a	0.03
LSD $_{0.05}$	0.10	0.002	0.01

2000 ppm
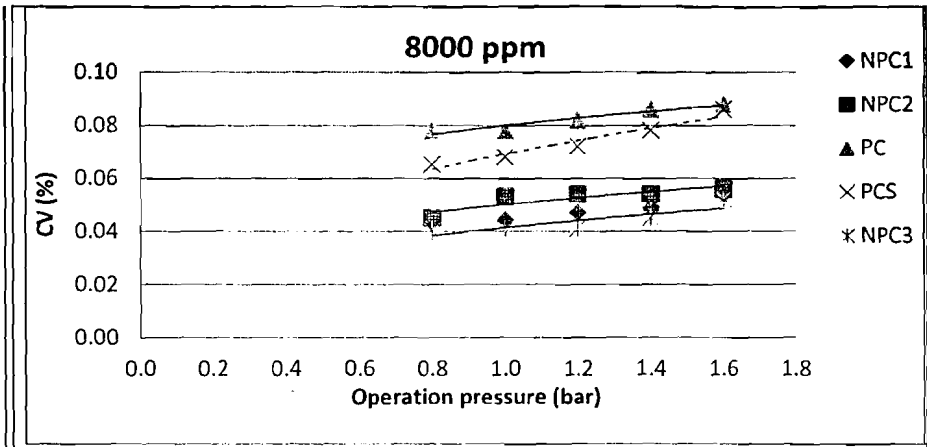

4000 ppm

6000 ppm
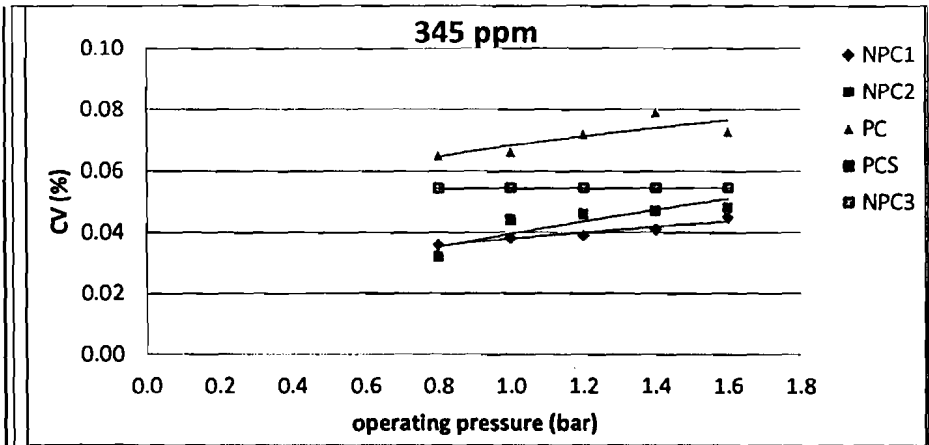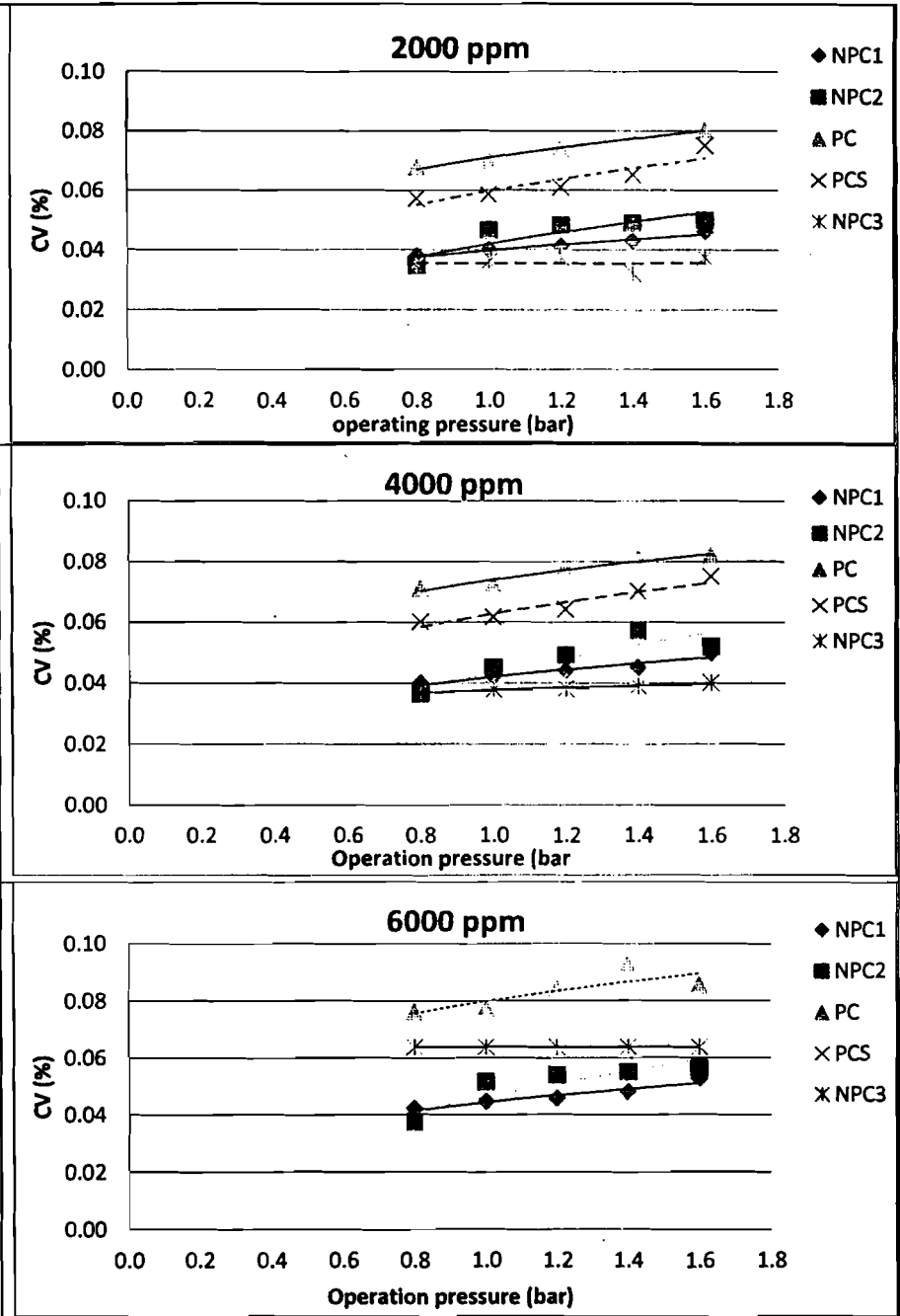
Fig. (5): The effect of emitter type on the coefficient of variation (CV) under different pressure head.

According to AE% for NPC3 emitter that recorded the highest value (94.74 %), while PCS and counted the lowest AE% (82.34) and other tested emitters were intermediate among. But it is logical values that obtained belong to the NPC1 (90.94%) and NPC2 (91.22%) emitters. Additionally, the lowest performance emitters were PC and PCS emitters due to their lowest AE% (89.51; 89.85%). The Same trend was attained after estimated DU; meanwhile, NPC1and NPC2 recorded the same value without significant difference. Whereas, PC and PCS still the lowest DU%.

Regarding to the coefficient of variation (CV), Table (10) and Figure (5) showed that the rank of emitter types can be in the following order: NPC3<NPC2<NPC1<PC<PCS. In addition, we can also notice that there are no significant differences between PC, PCS, NPC1, NPC2 and NPC3 in this concern. Resulted data are in agreement with those obtained by **Bralts, *et al.* (1978); Mansour *et al.* (2015); Mansour *et al.* (2016).**

Obtained results were in line with those obtained by **Keller and Bliesner (1990)** who reported that emitters are usually classified by the method in which they dissipate pressure or discharge characteristics, for instance, long path, vortex, orifice, flushing, continuous flushing, and multi-outlet emitters. Also, **Solomon (1979)** mentioned that the efficiency of drip

irrigation systems depends on the uniformity of emission rates throughout the system. An important factor affecting this uniformity is the unit-to-unit variation between emitters. The design of an emitter, the materials from which it is made, and the cares taken in the manufacturing processes affected the amount of such unit-to-unit variation that may be expected.

Table (11) and Figure (5) 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 a 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).

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/f to 1907 m^3/f at operation pressure 1 bar. The Same table showed root yield and Water crop productivity as affected by water salinity and emitter's type of turnip crops, it's clear that NPC2 emitter has a superior effect and recorded the highest value which ranged from 18.12 ton/f (4000 ppm) and 23.43ton/f (354 ppm) and 12.8; 9.1 kg/m^3 for 345 and 4000 ppm, respectively at 1 bar operation pressure. While comparing WCP for examined emitters, NPC2 had a primitive effect and recorded 14.5 and 17.4 % more thanNPC1 and NPC3 respectively.

With respect to salinity effect, it's clear to mention that; increase salinity associated with root yield and WCP. The rate of reduction in yield and WCP 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) at 1 and 1.2 bar operation pressure.

Meanwhile, Table (11) and Figure (5) discuss the impact of the investigated two parameters (water salinity and emitter's types) had a promise value or accepted trend.

Table (11): Distribution uniformity, Yield, and water crop productivity of turnip plant as affected by emitter types and water salinity under 1.0 bar operation pressure.

Dripper Type	Water salinity ppm	LR %	Du	Irrigation water consumed (m^3/fed)	Yield (ton/fed)	Water crop productivity (kg/m^3)
NPC3	345	10.0	0.91	1824	20.66 b	11.3 b
	2000	15.0	0.91	1907	19.45 c	10.2 d
	4000	20.0	0.91	1990	16.32 f	8.2 f
NPC2	345	10.0	0.92	1824	23.43 a	12.8 a
	2000	15.0	0.90	1907	21.74 b	11.4 b
	4000	20.0	0.88	1990	18.12 d	9.1 e
NPC1	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	18.81	9.9 b
				1907	21.10	11.1 a
				1907	17.77	9.4 b
Water salinity	LSD $_{5\%}$			1824	21.33	11.7 a
				1907	19.63	10.3 b
				1990	16.72	8.4 c

DU values were more constant under different emitters and there was no high difference within salinity treatment of each emitter. The highest and lowest values of DU at 1.0 bar were recorded at (4000 ppm) and the lowest one was recorded at 2000 ppm followed by 345 ppm. On the other hand, the values were obtained at NPC3 and NPC2 (0.92) and NPC1 (0.91) in same sequences. while at 1.2 bar operation pressure, were 95% and 93% were recorded at (NPC3+345 or 2000) and (NPC2 or NPC1 under 345 and 4000) for 1.2 bar, but in the case of ignoring salinity effect, DU NPC3 was better than NPC2 and NPC1 with increase percent 0.7%.The Same trend was obtained in the case of water salinity effect, where 345 and 2000 ppm gained the highest value 94% and 4000 gained 93% at 1.02 bar operation pressure.

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الملخص العربي

دراسات هيدروليكية لنظام الرى بالتنقيط تحت ظروف استخدام مياه منخفضة الجودة

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أجريت التجارب المعملية في قسم العلاقات المائية والري الحقلي التابع للمركز القومي للبحوث بالدقي- القاهرة- مصر، وذلك لإجراء تقييم هيدروليكي لخمسة أنواع من النقاطات واختيار أفضلهم للتطبيق في مزرعة المركز. أجريت التجارب الحقلية في مزرعة المركز للبحوث والانتاج بالنوبارية- البحيرة- مصر، خلال الموسم ٢٠١٦/٢٠١٥ وذلك لدراسة تأثير الأنواع المختلفة للنقاطات المختارة تحت معاملات مختلفة لملوحة مياه الري على صفات النبات والانتاج لمحصول اللفت.

أجريت التجارب المعملية لتقييم الأداء الهيدروليكي لخمس أنواع من النقاطات (On-line emitter NEIN-ETF) Built in (GR)، نقاط منظم للضغط (NEIN-PC)، نقاط منظم للضغط (EDEN-PC)، (KATIF-R-P-201) On-line emitter تحت درجات ملوحة (٢٤٥،٢٠٠٠، ٤٠٠٠، ٦٠٠٠، ٨٠٠٠ جزء في المليون) وتحت ضغوط تشغيل (٠.٨، ١.٠، ١.٢، ١.٤، ١.٦) بار. أما التجارب الحقلية فأجريت لدراسة تأثير أنواع النقاطات المختلفة ودرجات ملوحة مياه الري على صفات النبات والانتاجية لمحصول اللفت.

النتائج المعملية في حالة استخدام النقاطات (NPC1, NPC2, NPC3) تحت درجات ملوحة (٢٤٥، ٢٠٠٠، ٤٠٠٠ جزء في المليون) كانت الأعلى من حيث كفاءة الاضافة وانتظامية التوزيع و من الأفضل تطبيق هذه النقاطات في التجارب الحقلية.

بالنسبة للتجارب الحقلية أوضحت النتائج أن أعلى القيم كانت عند درجات ملوحة ٢٤٥ وذلك تحت كل النقاطات تحت الاختبار. أعلى انتاجية للمحصول كانت ٢٣,٤٣ طن/فدان باستخدام النقاط NPC2 بينما اقل انتاجية كانت ١٥,٧١ طن/فدان باستخدام النقاط NPC3 بفارق ١٦%، بينما سجل NPC2 أعلى كفاءة استخدام للمياة ١١,٤ كجم/م٢ بمعدل زيادة ١٤.٥% عن NPC1 و ١٦% عن NPC3. الانخفاض في الانتاجية وكفاءة استخدام المياة كان بمعدل ٣٥,٢٠ % وذلك تحت درجات ملوحة ٢٠٠٠، ٤٠٠٠ مقارنة بالكنترول ٢٤٥ جزء في المليون.

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