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Effect of Deficit Irrigation, Air injection and Nitrogen Fertilization on Water Productivity of Carrot under Subsurface Drip Irrigation System.

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Abstract

A field study was conducted in 2017-2018 to evaluate the effect of deficit irrigation, air injection and nitrogen fertilization on yield and water productivity of carrot under subsurface drip irrigation system. Experimental treatments were three levels ofdeficit irrigation (60%, 80% and 100%) of full crop water requirements and three types of nitrogen fertilizer(nitric acid(HNO3)48 % N, urea CO(NH2)2 46% N and ammonium nitrate(NH4NO3)33.5% N, with air injection treatment (12% air by volume of water). The results show that the yield and water productivity as well as the length of carrot root significantly increased for air injection treatments. On the other hand, the carrot diameter increase was not significant. The highest value of the carrot root yield (19.487 ton/fed) was obtained due to deficit irrigation 60% (I60%) and ammonium nitrate(NH4NO3)with air injection. Also, treatment of deficit irrigation (I80%) and urea fertilization CO(NH2)2 with air injection resulted 17.437 (ton/ fed) carrot roots which was significantly higher than that of non-air injection treatments. Also,the highest values of water productivity of carrot were 185.189 and 101.376 kg/m3obtained due to(I60%) with (NH4NO3)and co(NH2)2underair injection treatments, respectively. The highest lengths of carrot (cm) were 19.800 and 19.000 (cm)obtained due to (I80%) with CO(NH2)2and (I100%) with (NH4NO3), under air injection treatments, respectively. The highest values of carrotdiameter were 42.153 and 41.260 (mm) obtained due to treatment of full irrigation(I100%) and(NH4NO3) fertilizer withoutair injection and the treatment (I80%) and CO(NH2)2 fertilizer with air injection, respectively. Data from this study indicate that carrot yield and its water productivity can be improved byaerated sub surface drip irrigation system(SSDI).

Key words: Deficit Irrigation, Air injection, Nitrogen Fertilization, Water Productivity.

Introduction

FAO (2018) indicated that by 2025, 1800 million people are expected to be living in countries or regions with “absolute” water scarcity (<500 m3 per year per capita), and two-thirds of the world population could be under “stress” conditions (between 500 and 1000 m3 per year per capita).In fact, estimates suggests that by 2050, if we continue with our current approach to water management, global water demand will exceed supply by over 40%, which would put at risk 45% of global 52% of the world’s population, and 40% of grain production. This concern is supported by the World Economic Forum that consistently ranks water crises as a top global risk .

Osman et al (2015) indicated that the current economic and population growth as well as the prospective environmental challenges, Egypt is rapidly facing serious water scarcity issue. Water availability per capita rate is already one of the lowest in the world. In 2000, water withdrawal per capita was around 1000 m3. This is supposed to halve and fall below the scarcity rate by 2025. Also, per capita renewable water share has been declining from 853.5 m3 (2002) to 785.4 m3 (2007) and reached 722.2 m3 (2012). This is predicted to reach 534 m3 by 2030 (FAO, 2014).

Costaet al. (2007) indicated that the deficit irrigation strategies deliberately allow crops to sustain some degree of water deficit and sometimes, some yield reduction with a significant reduction of irrigation water. The classic deficit irrigation strategy (DI) implies that water is supplied at levels below full evapotranspiration (ETc) throughout the season.

Aeration Defined as the process by which air is mixed through water irrigation.

Goorahooet al. (2000) found that the concept of aerating the irrigation water increases the potential for the air to travel with water movement within the root zone. Physical, chemical, and biological soil characteristics that influence crop growth and yield depend on the relative proportions of the liquid and gas phases within the root zone. Generally, the incorporation of high efficiency aerogationin SSDI systems increased root zone aeration and can add value to grower investments in SSDI(Vyrlas at el. ,2014).

This study aimsat investigating the effect of deficit irrigation water, air injection and nitrogen fertilization under the sub-surface drip irrigation on carrot root production, growth parameters and Water Productivity (WP).

Materials and Methods

This experiment was carried out at the Experimental Farm of the Faculty of Agriculture, Benha University during the winter season of 2017/2018.

Particle size distribution of the soil used is as follow: s and8.57%, clay41.86% and silt49.57%, therefore the soil texture as clayey soil. Soil moisture content was 62.5 % at saturation point, while it was57.35% at field capacity and17.8% at welting point. So, the available moisture content is39.55%by volume.

2.1 Materials

The main and sub- main lines were 63and 25 mm diameter, respectively, of PVC pipe.16 mm diameter built-in drip liner with 4 Lph/30 cm ,flow rates under 1 bar operating pressure was used.

Acentrifugal pump type E5300 with operating pressure head ranged between 13.5 - 32 m and corresponding discharge rates ranged from 500 - 100 L/min. was used to connect directly by an electric motor of 2.25 kW power.

The air compressor used for air injection into the irrigationnet work was of 1 hp and average flow rate of 10 L/min at 1 bar pressure. The calibrated performance data of this compressor unit provided the ability to control the rate of air injected into the irrigation line to be 12% by volume of irrigation water, according to the recommendation of Bhattaraiet al. (2015),Abuarabet al. (2012) and Yuan at el. (2016).

The nitrogen fertilization was carried out through three types of nitrogen resources i.e.

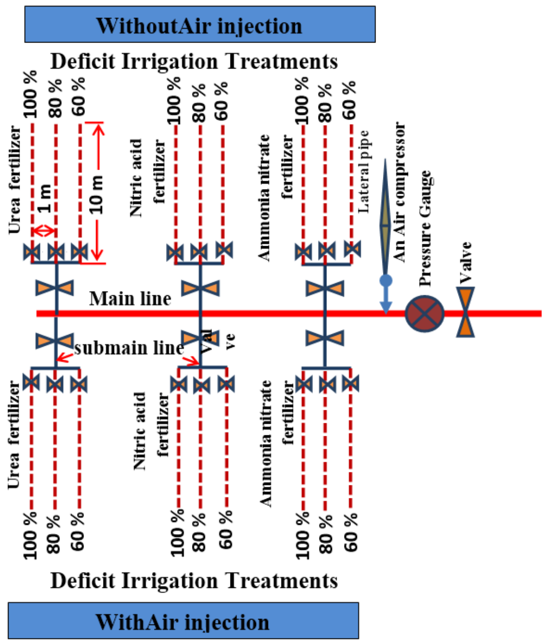
- Nitric Acid ($HNO3$) of 48 % N.
- Urea ($CO(NH2)2$) of 46 % N.
- Ammonium nitrate (NH_4 NO_3) of 33.5 % N.

The carrot seeds (Daucuscarota, Umbelliferae) supplied by Sakata company.

The diameter of the harvested carrot roots was measured by digital caliper , whereas the length of carrot plants and roots was measured by ruler.

2.2 The Experimental Design

The experimental design was a split plot with three replicates. The two air injection treatments (with air injection and without air injection) were allotted as main plots, the three nitrogen fertilization types (nitric acid,urea and ammonium nitrate fertilization) were allotted as submain plots, while the three levels of deficit irrigation (I60%, I80% and I100%) were randomly allotted in subplots. The experimental area was 900m2 (30×30 m) and area of each plot was 3 m2.



Planning of Experimental Treatments

2.3 Amount of Water Applied per each Irrigation

Quantity of the applied irrigation water was determined before each irrigation for all treatments. The applied irrigation water depth for carrot plant was determined according to water consumed during irrigation intervals as the difference between soil moisture content at field capacity and the moisture content at the next irrigation. Twenty one percent (21%) of the calculated water was added as a leaching requirement. The depth of water to be applied for each treatment was calculated according to the following equation:

$$\mathrm{Taw} = \left(\frac{\theta_{f.c} - \theta_{b.i.}}{100}\right) * \gamma_s * D_{rz}$$

Where

Taw total available water depth,(mm).

$\theta_{f.c}$ volumetric soil water content at field capacity,(%).

$\theta_{b.i.}$ volumetric soil water content before irrigation,(%).

γ_s Soil specific bulk density.

Drz the root zone depth, (mm).

The interval between successive irrigations was four days. The full irrigation treatment 100% (I100%) was equivalent of ETc of carrot crop. The deficit irrigation treatments I80% and I60% were 80 and 60 % from the full irrigation 100%.

2.4 Nitrogen Use Efficiency

The nitrogen use efficiency (NUE) is the ratio of crop yield to the amount of applied N, also called the partial factor productivity of applied N (PFPN).(Dobermann , 2005).

Sharma and Banik(2012) indicated that PFPN can be calculated from the equation:

$$PFPN = \frac{Y_N}{F_N}$$

Where
YN is crop yield (kg/fed).
FN is amount of fertilizer N applied (kg/fed).

All types of fertilizers were added with irrigation water at a rate of 500 - 1000 g m-3Nitrogen fertilizer , according tothe quantity of water applied per each irrigation and plant growth stage to be total of 70 kg / fed according to the recommendation of Hassan (1990).

2.5 Production of Carrot
The total carrot roots produced per Fadden was calculated as following:

$$\text{Carrot Production}\left({}^{Kg}/_{fed}\right) = \frac{\text{carrot root yield (kg)} \times 4200}{\text{sample area }(m^2)}$$

2.6 Water Productivity of carrot
The water productivity of carrot yield was calculated as following:

$$\text{Water productivity}\left({}^{kg}/_{m^3}\right) = \frac{\text{biomass of carrot yield }({}^{kg}/_{fed})}{\text{water applied }\left({}^{m^3}/_{fed}\right)}$$

Where, biomass inclusive plant plus **root.**

Results and Discussion

3.1Carrot root Length
Data in table 1 show the effect of deficit irrigation, type of nitrogen fertilization and air injection on length of carrot root (cm).The carrot root length was significantly affected by air injection treatments; however, it was not affected by fertilization treatments or deficit irrigation treatments. All the interactions between air injection X deficit irrigation , air injection X fertilization treatments, fertilization X deficit Irrigation and air injection X fertilization X deficit irrigation treatments were not significantly affect the carrot root length.
The highest value of the length of carrot root (19.80 cm) was obtained by treatment of 80% deficit irrigation (I80%), fertilization by(CO(NH2)2)and air injection. The treatment of 100 % deficit irrigation (I100%), fertilization with (NH4NO3), plus air injection, resulted in the second highest root length i.e. 19.000 (cm)

These results are in agreement with those of Carvalho et al. (2016) who found that the root carrot was influenced by different water depths (treatments).UNESP et al. (2015) found the bulb length, diameter and root length of radish crop increased due to increasing irrigation depth from 60% to 80% ETc. Dhungelet al. (2012) found that the use of aerated irrigation water (Oxygation) through root zone increased root volume.

3.2Carrot Root Diameter
Data in Table 2 show the effect of deficit irrigation, type of nitrogen fertilization and air injection on diameter of carrot root (mm). Results of statistical analysis indicated that, the carrot root diameter was not significantly affected by air injection treatments, deficit irrigation treatments, fertilization treatments, or by any interaction between each of them with other treatments.

The highest values of the diameter of carrot root (mm) were 42.153 and 41.260 mm obtained by 100% full irrigation (I100%) , fertilization with (NH4NO3) without air injection and 80 % deficit irrigation (I80%), fertilization CO(NH2)2 with air injection, respectively.

3.3 Carrot production
Data in Table 3showthe effects of deficit irrigation, nitrogen types and air injection on carrot yield production (ton/fed) during the growing season 2017-2018. No significant differences in carrot yield could be observed due to the deficit irrigation treatments. The root carrot weight was significantly increased by air injection treatments. Interactions between each of air injection X fertilization treatments, deficit irrigation X fertilization treatments and air injection X fertilization X deficit irrigation treatments had significant effects on carrot yield.

The highest values of the carrot root production (ton/fed) were obtained due to 60% deficit irrigation (I60%) , fertilization by ammonium nitrate fertilizer (NH4NO3)and air injection followed by 80 % deficit irrigation (I80%), fertilization by urea(CO(NH2)2) with air injection which resulted in 19.487 and 17.437 (ton/ fed), respectively.

Table 1. Length of carrot root (cm) as affected by air injection, fertilization type and deficit irrigation system under SSDI.

Air Injection treatment	Fertilization treatment	Deficit Irrigation treatment %60	%80	%100	Mean
with	CO(NH2)2	18.967	19.800	17.933	18.900
	NH4NO3	17.100	16.900	19.000	17.667
	HNO3	16.467	16.733	17.967	17.056
mean		17.511	17.811	18.300	17.874
Without	CO(NH2)2	15.833	16.733	16.533	16.366
	NH4NO3	14.200	15.533	14.667	14.800
	HNO3	15.367	15.567	16.633	15.856
Mean		15.133	15.944	15.944	15.674
G. Mean		16.322	16.878	17.122	
Mean of fertilization X deficit Irrigation					
	CO(NH2)2	17.400	18.267	17.233	17.633
	NH4NO3	15.650	16.217	16.833	16.233
	HNO3	15.917	16.150	17.300	16.456

LSD at 0.05: LSD for Factor Air Injection = 1.130
LSD for Factor Fertilization = N.S
LSD for Factor Deficit Irrigation = N.S.
LSD for Factor Air Injection X Fertilization = N.S.
LSD for Factor Air Inject. X Def. Irri. = N.S.
LSD for Factor Fert. X Def. Irri. = N.S.
LSD for Factor Air Inject. X Fert.X Def. Irri. = N.S.

Table 2. Diameter of carrot root (mm) as affected by air injection, fertilization type and deficit irrigation systems under SSDI.

Air Injection treatment	Fertilization treatment	Deficit Irrigation treatment %60	%80	%100	Mean
with	CO(NH2)2	37.800	41.260	40.860	39.973
	NH4NO3	38.233	36.977	37.360	37.523
	HNO3	35.003	31.247	37.343	34.531
mean		37.012	36.494	38.521	37.342
without	CO(NH2)2	36.980	39.753	37.180	37.971
	NH4NO3	38.503	34.213	42.153	38.290
	HNO3	37.397	37.437	38.417	37.750
Mean		37.627	37.134	39.250	38.004
G. Mean		37.319	36.814	38.886	
Mean of Fertilization X Deficit Irrigation					
	CO(NH2)2	37.390	40.507	39.020	38.972
	NH4NO3	38.368	35.595	39.757	37.907
	HNO3	36.200	34.342	37.880	36.141

LSD at 0.05: LSD for Factor Air Injection = N.S.
LSD for Factor Fertilization = N.S.
LSD for Factor Deficit Irrigation = N.S.
LSD for Factor Air Injection X Fertilization = N.S.
LSD for Factor Air Inject. X Def. Irri. = N.S.
LSD for Factor Fert. X Def. Irri. = N.S.
LSD for Factor Air Inject. X Fert.X Def. Irri. = N.S.

Table 3. Production of carrot yield (ton/fed) as affected by air injection, fertilization type and deficit irrigation under SSDI.

Air Injection treatment	Fertilization Treatment	Deficit Irrigation Treatments %60	%80	%100	Mean
With	CO(NH2)2	11.957	17.437	16.697	15.363
	NH4NO3	19.487	15.090	10.960	15.179
	HNO3	9.383	13.420	15.767	12.857
mean		13.609	15.316	14.474	14.466
Without	CO(NH2)2	10.723	12.577	9.967	11.089
	NH4NO3	8.180	12.553	11.047	10.593
	HNO3	5.053	13.417	12.020	10.163
Mean		7.985	12.849	11.011	10.615
G. Mean		10.797	14.082	12.743	
Mean of Fertilization X Deficit Irrigation					
	CO(NH2)2	11.340	15.007	13.332	13.226
	NH4NO3	13.833	13.822	11.003	12.886
	HNO3	7.218	13.418	13.893	11.510

LSD at 0.05 : LSD for Factor Air Injection = 1.591 .
LSD for Factor Fertilization = N.S.
LSD for Factor Deficit Irrigation = N.S.
LSD for Factor Air Injection X Fertilization = 2.756 .
LSD for Factor Air Inject. X Def. Irri. = N.S.
LSD for Factor Fert. X Def. Irri. = 3.375 .
LSD for Factor Air Inject. X Fert.X Def. Irri. = 4.774 .

These results may be attributed to the suitable balance between air and soil moisturedue to air injection.Also, the deficit irrigation and air injection probably provided the root zone conditions favorite for activating the growth of carrot plant.

These results are in agreement with Liuet al. (2016) who found that the deficit irrigation (at 80% of FI) was the suitable mode of water and nitrogen management for Arabica coffee.Bhattaraiet al. (2006) found that the aeration(12% air in water) increased the tomato fruit yield by 21% compared with the control (4.2 kg versus 3.7 kg per plant).Bhattaraiet al. (2004) found that increased aeration of the root zone in heavy clay soils caused beneficial effects to SSDI irrigated crops, irrespective of the soil water conditions, and could add value to grower investments in SSDI.

Water Productivity of Carrot Yield

Data in Table 4 show the effect of deficit irrigation, type of nitrogen fertilization and air injection on water productivity of carrot yield (kg/m3). Results indicate that, the water productivity carrot root weight (kg/m3)was significantly affected by air injection treatments, fertilization treatments , interaction between air injection X deficit irrigation, interaction between air injection Xnitrogen fertilization treatments, interaction between nitrogen fertilization X deficit irrigation and, interaction between air injection X nitrogen fertilization X deficit irrigation treatments, also No significantly affected by deficit irrigation treatments. In spite of the statistic alanalys is results, it could be observed a slight increasing trend in water productivity with deficit irrigation and it was more clear under air injection treatments. This increasing trend in water productivity was expected due to the less water applied under deficit irrigation
conditions with no significant effect on carrot production.

Therefore, the highest values of the water productivity of carrot yield (kg/m3) were obtained due to 60% deficit irrigation (I60%) , fertilization with(NH4NO3) and air injection and then followed by the treatment of same 60 % deficit irrigation (I60%), and air injection but except fertilization was byCO(NH2)2, which gave 185.189 and 101.376 (kg/ m3), respectively.

Table 4. water productivity of carrot(kg/m3)as affected by air injection, nitrogen fertilization type and deficit irrigation system under SSDI.

Air Injection treatment	Fertilization treatment	Deficit Irrigation treatment			Mean
		%60	%80	%100	
	CO(NH2)2	101.376	87.979	61.127	83.494
with	NH4NO3	185.189	80.312	40.044	101.849
	HNO3	79.370	73.714	60.386	71.156
mean		121.978	80.668	53.852	85.499
	CO(NH2)2	93.045	69.309	32.784	65.046
without	NH4NO3	75.322	68.992	38.073	60.796
	HNO3	35.610	65.782	47.995	49.796
Mean		67.993	68.028	39.617	58.546
G. Mean		94.986	74.348	46.735	
Mean of fertilization X deficit irrigation					
	CO(NH2)2	97.211	78.644	46.955	74.270
	NH4NO3	130.256	74.652	39.059	81.322
	HNO3	57.490	69.748	54.190	60.476

LSD at 0.05 :LSD for Factor Air Injection = 9.684. LSD for Factor Fertilization = 11.860.
LSD for Factor Deficit Irrigation = N.S. LSD for Factor Air Injection X Fertilization = 16.773.
LSD for Factor Air Inject. X Def. Irri. = 16.773. LSD for Factor Fert. X Def. Irri. = 20.542.
LSD for Factor Air Inject. X Fert.X Def. Irri. = 29.051.

In general, it could be concluded that, water productivity was increased with air injection as well as with deficit irrigation under all the tested types of N-fertilizers. The quantity of water added at I60%, I80% and I100% treatments were 394.548 , 526.008 and 657.552 m3/fed, respectively.

3.5 Effect of air injection treatments on the partial factor productivity of nitrogen (PFPN):

Data in Table 5 and Figure 1 show that, the partial factor productivity of nitrogen (PFPN, kg of carrot roots /kg of applied N) was highly increased by air injection treatments. The highest values of the partial factor productivity of nitrogen 215.168 and 212.591(kg carrot roots /kg N) were obtained by nitrogen fertilization with urea CO(NH2)2 and nitrogen fertilization with ammonium nitrate (NH4NO3) under air injection treatments, respectively. The percentage of increase in the partial factor productivity of nitrogen due to air injection treatment was 36.3 % compared with the no air injection treatment.

Table 5. The partial factor productivity of nitrogen (PFPN, kg root carrot /kg N) as affected by air injection treatments and fertilization type under SSDI.

Air injection treatments	Nitrogen fertilization treatments			Average
	CO(NH2)2	NH4NO3	HNO3	
Air injection	215.168	212.591	180.070	202.610
Non-air injection	155.308	148.361	142.339	148.670

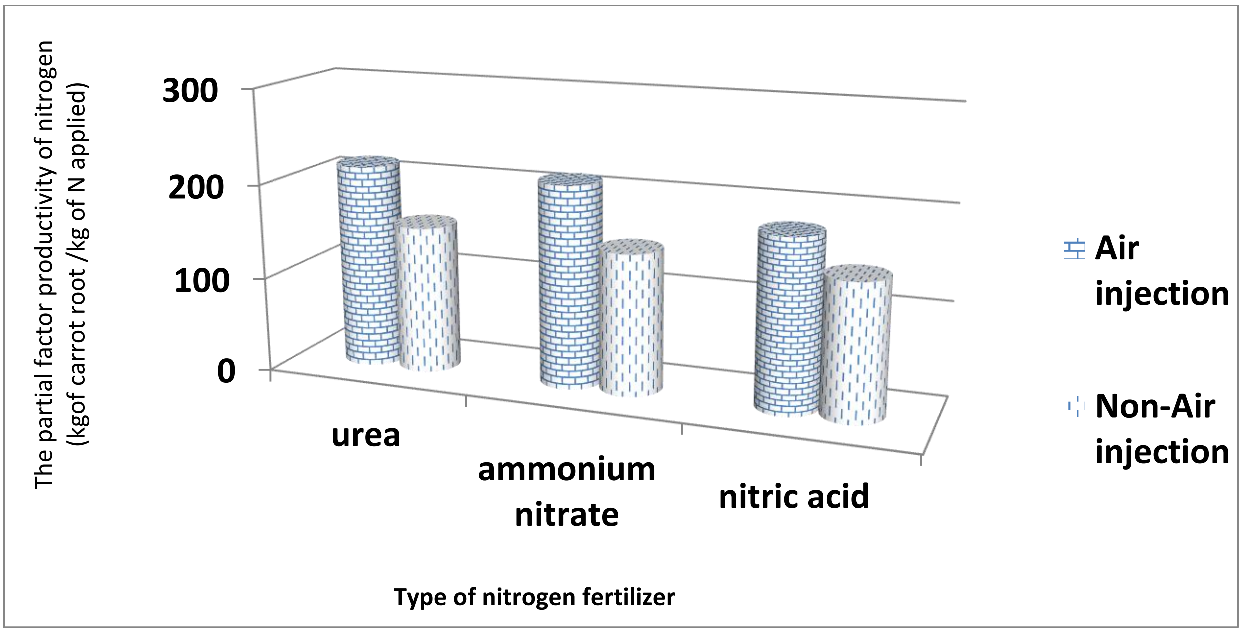


Figure 1. Therelationship between nitrogen fertilization types and the partial factor productivity of nitrogen (PFPN, Kg of carrot root /Kg of N applied) under air injection and no air injection condition.

3.6 Effect of air injection and deficit irrigation level on the partial factor productivity of nitrogen (PFPN):

Data in Figure 2 show that the partial factor productivity of nitrogen was higher for all air injection under deficit irrigation levels. The highest values of the partial factor productivity of nitrogen were 272.927 and 244.216 (kg root carrot /kg N) obtained under air injection treatment from deficit irrigation 60% (I60%) with nitrogen fertilizer of ammonium nitrate (NH4NO3) and deficit irrigation 80% (I80%) with nitrogen fertilizer of urea CO(NH2)2, respectively**.**

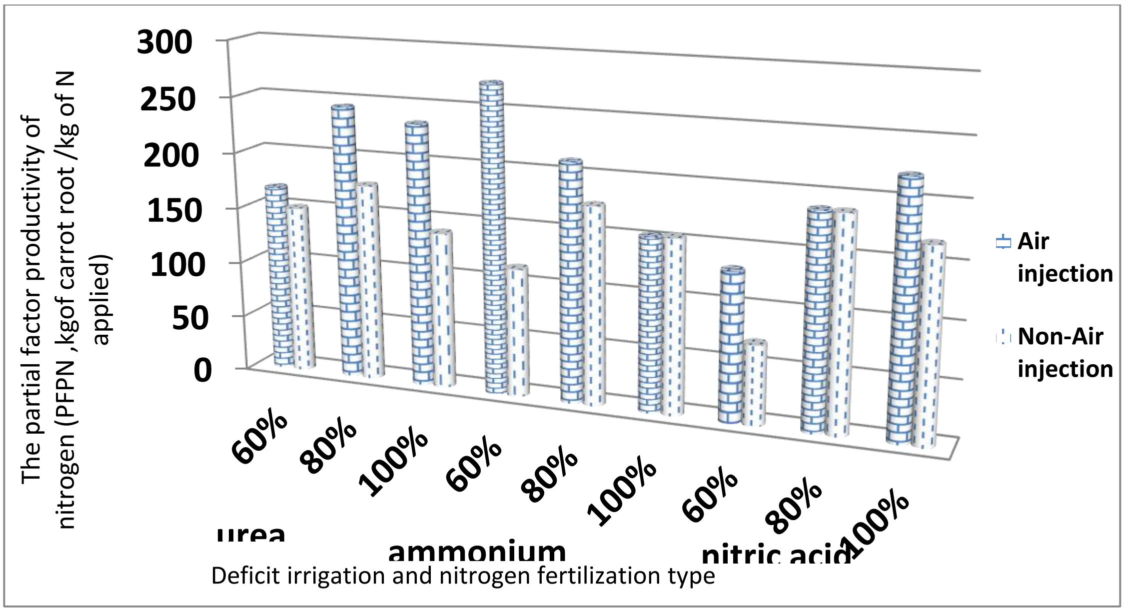


Figure2. The relationship between deficit irrigation levels, nitrogen fertilization types and the partial factor productivity of nitrogen (PFPN, Kg of carrot root /Kg of N applied) with air injection treatments.

Conclusions

The objectives of this study were to evaluate the effect of deficit irrigation, air injection and nitrogen fertilization type on water productivity under subsurface drip irrigation. The results of this study showed that :

1- Deficit irrigation strategy is useful to save the water for the agricultural purposes.
2- Air injection technique is essential to increase the production and water productivity of the crops.
3- The deficit irrigation is useful for increasing the root crop production.
4- An increase percentage of 36.3 % in the partial factor productivity of nitrogen occurred due to air injection compared with noair injection treatment under all deficit irrigation and all types of fertilizers.
5- The best production and water productivity of the carrot crop were obtained due to I60% and I80% deficit irrigation with air injection technique.
6- The average length of carrot roots was significantly affected by air injection.
7- The carrot rootdiameter did not significantly affectedbythe deficit irrigation with air injection orwithout air injection treatments.

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تأثير الري الناقص وحقن الهواء والتسميد النيتروجيني على الأنتاجية المائية لمحصول الجزر تحت نظام الري بالتنقيط تحت السطحي.

احمد المؤيد1؛ محمد الأنصارى2؛ منتصر عواد3؛ ابوسريع فرج4

1: طالب دراسات عليا، 2: أستاذ ؛3: استاذ م. ؛ 4: مدرس هندسة النظم الزراعية والحيوية بكلية الزراعة جامعة بنها

أجريت الدراسة في المزرعة البحثية لكلية الزراعة بمشتهر – جامعة بنها وكانت معاملات التجربه ثلاثة مستويات من الري الناقص من الأحتياجات المائية للمحصول(I100% , I80% ,I60%) وثلاثة انواع من الأسمدة النتروجينية (حمض النتريك 48% ، يوريا 46% ، نترات الأمونيوم 33.5%) بتركيز (500 –1000 ppm) ومعاملتي ضخ هواء 12% من كمية المياه المضافة وبدون ضخ هواء. وكانت النتائج كما يلي :

-أعلى قيم لأنتاجية محصول الجزر (طن / فدان) اعطيت بالمعاملة 60% ري ناقص (I60%) و سماد نترات الأمونيوم 33.5% وحقن هواء (12% هواء من كمية المياه المضافة) والمعاملة 80% ري ناقص (I80%) و سماد يوريا 46% وحقن هواء (12% هواء من كمية المياه المضافة) وكانت 19.487 و17.437 طن /فدان على التوالي.

- أعلى قيم للأنتاجية المائية للمحصول الجزر(كجم/متر3) أعطيت بالمعاملة 60% ري ناقص (I60%) و سماد نترات الأمونيوم 33.5% وحقن هواء (12% هواء من كمية المياه المضافة) والمعاملة 60% ري ناقص (I60%) و سماد يوريا 46% وحقن هواء (12% هواء من كمية المياه المضافة) وكانت 185.189 و 101.376كجم/متر3 على التوالي.

- أعلى قيم لطول محصول الجزر(سم) أعطيت بالمعاملة80% ري ناقص (I80%) و سماد يوريا 46% وحقن هواء (12% هواء من كمية مياه الري المضافة) والمعاملة 100% ري ناقص (I100%) و نترات الأمونيوم 33.5% وحقن هواء (12% هواء من كمية المياه المضافة) وكانت 19.800 و 19.000 سم على التوالي.

- أعلى قيم سمك (قطر) لمحصول الجزر(مم) وكانت 42.153 و 41.260 مم أعطيت من المعاملة100% ري كامل(I100%)مع سماد نترات الأمونيوم 33.5%أزوتفي عدم حقن هواء والمعاملة 80% ري ناقص (I80%) وسماد يوريا 46%مع حقن هواء (بمعدل حقن هواء12% من كمية مياه الري المضافة) على التوالي.

- كانت كفاءة استخدام السماد النتروجيني في معاملات الري الناقص وحقن الهواء12(%هواء من كمية المياه المضافة) أعلى بزيادة 36.3% مقارنة بمعاملات الري الناقص بدون حقن هواء.