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Impact of Irrigation Water Source on Microirrigation Systems Performance and Productivity of Leaf Vegetable Crops

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ABSTRACT

Two field experiments were carried out during summer seasons of 2019 and 2020 in Horticulture farm, Faculty of Agricultural, Kafr El-Sheikh University, North of the Nile Delta, Egypt, having a clay textured soil to evaluate the effect of drainage of fish ponds on microirrigation systems performance and summer cabbage production. Study variables were; two microirrigation systems (drip system "D" and microsprinkler system "MS"), two sources for irrigation (traditional water “TW” and drainage of fish ponds “DF”) and three nitrogen doses (100% N, 70% N and 40% N). For traditional water “TW” (100% N) only was applied. The results referred to that, “DF” increased the reduction in emitter flow rate at end of growing season comparing with “TW”. The lowest reduction was achieved by (TW+ 100% N) as 6.1 and 3.0 % for “D” and “MS” systems respectively. The highest uniformity coefficient (CU) at end of growing season achieved by (TW+ 100% N) as 87 and 84 % for “D” and “MS” systems respectively. “D” system achieved the highest head yield while “MS” system achieved the highest head diameter. The highest head yield was achieved by (DF + 100% N) as 110 and 87.4 ton/fed. for “D” and “MS” respectively. The highest values of water productivity were obtained by (DF + 100% N) as 49.7 and 44.7 kg/m^3 for “D” and “MS” respectively. The highest values of nitrogen productivity were obtained by (DF + 40% N) as 1170.8 and 1045.8 kg$_{yeild}$/kg$_N$ for “D” and “MS” respectively.

Keywords: fish pond water, Microirrigation Systems, cabbage productivity, water productivity

INTRODUCTION

Finding alternative sources for irrigation water is one of the important solutions in confrontation water shortage problem in Egypt. This includes for example desalinating brackish water Ali *et al.* (2009), wastewater “urban, treated and reclaimed” Zhou *et al.* (2015), drainage water Gabr (2018) and dairy farm effluent Ali *et al.* (2007). One of the appropriate and safe sources for irrigation is water drained from fish farms because it rich with nutrients and can be potential sources of irrigation and fertilization simultaneously. Supplying fertilizer throughout growing season by fish effluents is appropriate for leaf vegetable crops which its production based on vegetative growth, where it has positive effects on growth and development of plants. Nhan *et al.*(2008) refereed to that only 5-6% of the added N, OC or P in the fish basins were consumed by harvested fish, about 29% of N, 81% of OC and 51% of P collected in the sediments and the remaining parts have been lost by discharging the basins in drainage.

Hussein and Al-Jaloud (1995) used drainage of fish ponds “FW” to irrigate wheat crop and compared with well water “WW”; “FW” increased wheat grain yield and water productivity of 15.6 and 36.4 % respectively more than “WW”. The same effect of fish effluents in Asia Pacific region was obtained by Wood *et al.* (2001). Porrello *et al.* (2005) and Elnwishy *et al.* (2006) pointed out to fish effluents as a rich source of main nutrients can enhance soil fertility and crops productivity and minimize mineral fertilizers applied. Sikawa and Yakupitiyage (2010) assessed the impact of filtration process of fish effluent on lettuce production. Lettuce head yield increased significantly under filtered water comparing with unfiltered water. The results summarized that filtration of water drained from fish farms had an appropriate tissue N content and supply an opportunity to use it in vegetable crop production. Eid *et al.* (2013) and (2014) and Okasha *et al.* (2016) stated that replacing irrigation water “IW” with drained water from fish farms “FW” saved 100 % of irrigation water and 40 and 20 % of mineral fertilizers for potato and soybean crops respectively. Raising available bio-components and dissolved elements in “FW” contribute to enhance the yield.

The main disadvantage of reusing drained water from fish farms with microirrigation system is emitter clogging where organic material of fish effluents accumulated inside emitters and cause plugging. Al-Muhammad *et al.* (2016), Feng *et al.* (2018), Li *et al.* (2019) and Zhou *et al.* (2019) emitter clogging depends mainly on two factors, irrigation water quality and emitter flow path design and occurs in three types physical, biological and chemical. Emitter clogging types do not happen independently; they usually interacted and combined as the complex-clogging. Wu *et al.* (2008) classified clogging degree according to reduction in flow rate as fallow: unclogging “< 5 %”, slightly clogged “5–20 %”, generally clogged “20–50 %”, seriously clogged “50–80 %” and completely clogged “> 80 %”. Liu and Huang (2009) and Ismail *et al.* (2013) evaluated coupled effect of treated wastewater and emitter types on clogging ratio. The

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results referred to increase clogging ratio for in line emitter type more than for on line type; increasing emitter discharge decreased clogging ratio. Increasing levels of bacteria in water source cause accelerate slime buildup and sever clogging happen. Eid and Hoballah (2014) evaluated emitter clogging ratio for drip irrigation system using two sources of irrigation water, fish effluent "FE" and traditional water "TW". The results stated that, "FE" increased clogging ratio more than "TW".

Ghaemi and Chieng (1997) resulted that main variation in emitter discharges in lateral line within irrigation system caused by emitter clogging; a few clogging can cause a greatly reduce in application uniformity. Irrigation uniformity for sprinkler system is classified low if Christiansen uniformity coefficient (CU) was less than 70 %; (CU) should be more than 80 % in case of chemigation. Keller and Bliesner (2000) recommended that in general the optimum value of CU for deep rooted crops is ranged from 75 to 85 % and for shallow rooted crops is 85 %. Rowan *et al.* (2013) classified uniformity coefficient (CU) as >89% excellent, 80-89% good, 70-79% fair, and <70% poor.

The present study was carried out to study and identify the following main objectives i) evaluate the impact of fish effluent on microirrigation system performance. ii) determine the impact of different types of irrigation water and microirrigation system on leaf vegetable crop (summer cabbage).

MATERIALS AND METHODS

1. Experimental soil preparation and soil analysis

A field experiment was carried out during two summer seasons of 2019 and 2020 from April to August in Horticulture research farm, Faculty of Agriculture, Kafrelsheikh University, North of the Nile Delta, Egypt.

Soil texture classified as clay soil; the mechanical analysis of the experimental soil is presented in Table 1.

Table 1. Mechanical analysis of the experimental soil.

Soil depth, cm	Particle size distribution			Soil texture	Bulk density, g/cm^3	Field capacity, %	Permanent wilting point,%	Available water, %
	Sand,%	Silt, %	Clay,%					
0-15	18	25	57	Clay	1.22	44.80	21.36	23.44
15-30	21	24	55	Clay	1.27	41.45	21.40	20.05
30-45	19.4	28.6	52	Clay	1.35	39.00	21.00	18.00

Experimental soil was prepared in the traditional method (Chiseling twice + leveling) and furrowed at 70 cm width. For two seasons the field was flooded in April and Cabbage "OS cross" variety was transplanted manually at a distance of 30 cm on the furrow two days after flooding and harvested in August based on every irrigation system.

2. Fish ponds

The ponds were built by brick with a height of 1.5 m; inner sides were painted with weather-coat to protect it from splash. The fish ponds contain Nile tilapia 100 fish m^{-3} and 50 g/fish initial weight. The fish were fed a commercial feed daily by a rate of 6 % body weight. About 15 % of ponds water was drained to collection pond and replaced by new fresh water.

Chemical analysis of open channel water (traditional water) and fish effluent (drained water from fish ponds) for experimental site presented in Table 2.

Table 2. Some chemical analysis of applied water (open channel and fish effluent) for experimental site.

Properties		Open channel water (traditional)	Fish effluent (fish pond)
1	Potential of Hydrogen, (PH)	7.2	7.55
2	Electrical conductivity, (EC, mg L^{-1})	725	803
3	Total dissolved solids, (TDS, mg L^{-1})	193	411
4	Ammonia, (NH_3, mg L^{-1})	0.013	0.180
5	Nitrite, (NO_2, mg L^{-1})	0.022	0.211
6	Nitrate, (NO_3, mg L^{-1})	0.65	1.66
7	Biological Oxygen demand, (BOD, mg L^{-1})	2.53	6.72
8	Total suspended solids, (TSS, mg L^{-1})	95	152
9	Dissolved oxygen, (DO, mg L^{-1})	3.1	4.3

mg.L^{-1}: milligram per litter

3. Irrigation network

Main irrigation network was constructed to irrigate horticulture farm and refill fish ponds. The irrigation network components are centrifugal pump with discharge of 60 m^3/h driven by 14.8 kW (20 hp) electrical engine, control valve, filtration unit (2 media sand filter and steel screen filter 120 mesh) with diameter of 4". The main line with 4" diameter made from HDPE, it was used to supply the water to other parts of the farm. A sub main line PE with 32 mm was used to feed the laterals from main line or from fish pond. The lateral lines PE with 16 mm inner diameter and 20 m length were used for two irrigation systems. A 0.74 kW (1.0 hp) electrical engine was fixed on collection fish pond to transfer the water to fish effluent treatments. For drip irrigation system; long-path emitters with 0.7 mm flow cross section diameter, 4.0 L/h flow rate at 1.0 bar operating pressure and 30 cm distance between emitters were used. The emitter is classified in-line type (GR). For microsprinkler system the rotator micro-sprinklers with 94.0 L/h flow rate and 2.0 m radius of throw at 1.0 bar operating pressure were used. The rotor micro-sprinklers were connected with lateral line by 8.0 mm diameter spaghetti tube. Sprinklers were fixed in the field at a distance of 2.0 m (100 % overlapping) using 120 cm stake height. Control valve and pressure gauge was used for every treatment to calibrate operating pressure. Pressure differential tank was used to add recommended dose of nitrogen for leaf vegetable crops (120 kg N/fed.) in form of ammonium nitrate (33.5% N) (Abd El-Aal and El-Sharkawy, 2011).

Fertilizer was applied in three equal doses at 3rd, 5th and 7th week from transplanting. Experimental field design shown in Fig. (1).

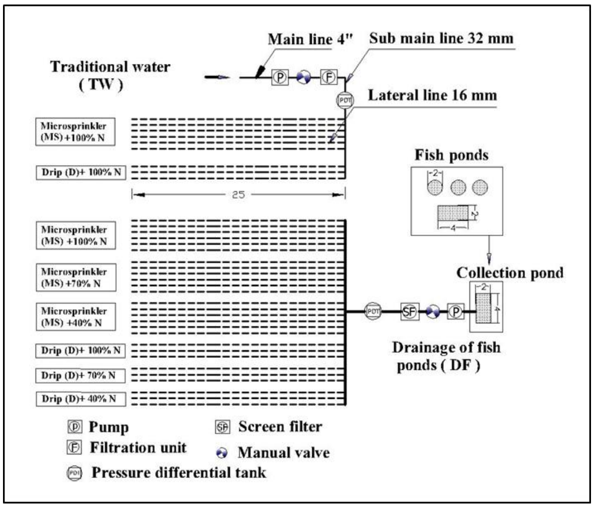

Fig. 1. Experimental field layout and treatments distribution

4. Study variables

a. **Irrigation system:** two systems of microirrigation systems were applied (drip "D" and microsprinkler "MS");

b. **Water source:** the water for irrigation was obtained from two sources, Nile water from open canal (traditional water, TW) and fish ponds (drainage of fish ponds "DF");

c. **Nitrogen dose:** three doses from recommended nitrogen dose (100% N, 70% N and 40% N) were applied for drainage water of fish pond treatments, while 100% N only was applied for traditional water treatments.

5. Evaluation of seasonal irrigation requirements

Seasonal irrigation requirements for summer cabbage based on Penman-Monteith equation were calculated using CROPWAT 8 software program (Allen *et al.*, 1998). The potential evapotranspiration for summer cabbage was estimated according to the climatological data of the experimental site which collected by the Climate Station at Rice Research and Training Centre, Sakha, Kafr-Elsheikh. Cabbage crop coefficient (Kc) values for growing season showed in Fig. (2).

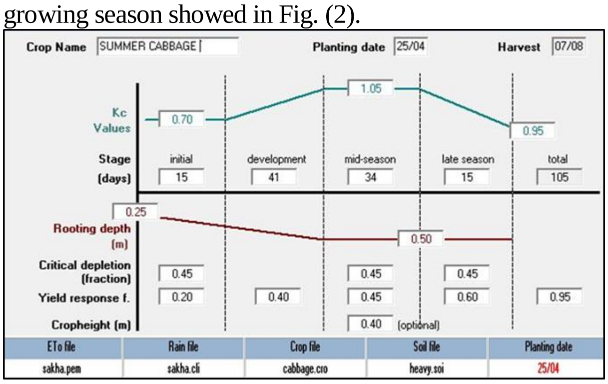

Fig. 2. Summer cabbage crop coefficient (kc) values at a growing stages.

Growing season for summer cabbage in clay soil ranged from 90 to 120 days in normal conditions, but irrigation system was an influence factor for growing season length. Under drip irrigation summer cabbage was matured 105 days after transplanting. Under micro-sprinkler irrigation, the cabbage arrived to full growing after 87 days from transplanting so the irrigation discontinued to avoid head rot. Total applied water (m^3/fed.) during growing season including pre-planting irrigation presented in Table (3).

Table 3. Seasonal applied water for summer cabbage crop, m^3/fed.

Days	Month	Stage	Drip	Microsprinkler
6	April	pre-planting	200	200
31	May	Init. + Deve.	496.0	528.5
30	Jun	Deve. + Mid.	671.1	715.0
20	Jul	Mid.	479.4	510.8
11	Jul	Mid.	223.3	0
7	Aug	Late	144.3	0
105 days			2214.2	1954.3

6. The reduction in emitter flow rate

Reduction in emitter flow rate at end of every season was calculated using Eq. 1 and 2 Li *et al.* (2019):

$$q_r = 100\ x\ (\frac{q_e}{q_i}) \quad (1)$$

$$q_c = 100\ x\ (1 - q_r) \quad (2)$$

In which q_r is the relative emitter flow rate (%); q_e is the mean emitter flow rate at end of season (L/h); q_i is the mean initial emitter flow rate (L/h) and q_c is the reduction in flow rate (%).

7. Uniformity of emitter flow rate

Uniformity of emitter flow rate along the lateral line for two irrigation systems was calculated at start and end of the experiment for two seasons to evaluate the impact of water source on the uniformity. Christiansen uniformity coefficient (CU) was used to express the uniformity according to James (1988). Eq. 3 was used:

$$CU = 100\ X\ (1.0 - \frac{\sum_{i=1}^{n} |x_i - x^\backslash|}{n\, x^\backslash}) \quad (3)$$

In which x_i is the volume caught at observation point i; $x^\backslash$ is the average volume amount caught and n is the number of observations.

8. Total cabbage head yield and head diameter:

At end of growing season (105 and 87 days for drip and microsprinkler systems respectively) total head yield (ton/fed) based on weight of fresh head and mean head diameter (cm) were measured

9. Water productivity (WP)

Water productivity referred to crop yield per unit of water applied (kg/m^3). It was calculated using Eq. 4.

$$WP = \frac{Y}{W} \quad (4)$$

In which Y is the cabbage total head yield kg/fed. and W is the total applied water m^3/fed.

10. Nitrogen productivity (NP)

Nitrogen productivity was characterized as crop yield per unit of nitrogen added (kg $_{yield}$/kg $_N$). It was calculated using Eq. 5.

$$NP = \frac{Y}{N} \quad (5)$$

In which N is the total applied nitrogen (recommended dose = 120 kg N/fed.).

11. Statistical Analysis:

Experimental design was split plot design: main plot factor (irrigation system) and sub plot factor (water source + nitrogen level). Analysis of variance and significant differences between means at 5% level was analyzed by CoStat statistical software program.

RESULTS AND DISCUSSION

1. The reduction in emitter flow rate

Average of the reduction in emitter flow rate at end of growing seasons as affected by irrigation system, water source and nitrogen dose are illustrated in Fig. (3). The statistical analysis referred to high significant effect of two factors and their interaction (R^2 = 0.995) on the reduction in emitter flow rate at end of growing seasons at significance level 0.05. The highest effect was obtained by (DF + 100% N) treatments for two irrigation systems, where the reduction was 20.1 % under "D" system and 13.1 % under "MS" system. The lowest effect was achieved by (TW + 100% N) treatments, where it was 6.1 % under "D" system and 3.0 % under "MS" system. These results may be caused by organic sediments which included in fish water. So the screen filter for drainage of fish ponds needed to wash every event where the sediments precipitate density around the screen which cause decrease in pressure. "D" system had the highest effect comparing with "MS" system. This result can be attributed to increase orifice diameter for micro-sprinklers more than drippers. Increasing nitrogen dose increased the concentration of dissolved mineral fertilizer in applied water so the reduction in emitter flow rate for two systems increased.

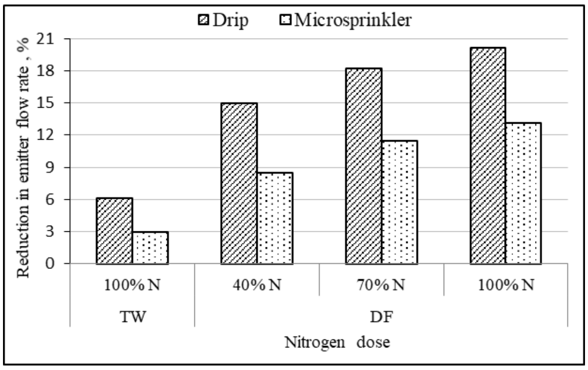

Fig. 3. Effect of water source and nitrogen dose on reduction in emitter flow rate at two irrigation systems.

The reduction in emitter flow rate for different treatments classified to degree of clogging according to Wu *et al.* (2008) and showed in Table (4). Under "D" system the reduction in flow rate classified slightly clogged for different treatments except (DF + 100% N) treatment classified generally clogged. Under "MS" system the reduction in flow rate classified unclogging for (TW + 100% N) treatment and slightly clogged for "DF" treatments.

Table 4. Classification the reduction in emitter flow rate for different treatments

Irrigation system	TW	DF		
	100% N	40% N	70% N	100% N
Drip "D"	slightly	slightly	slightly	generally
Microsprinkler "MS"	unclogging	slightly	slightly	slightly

2. Uniformity of emitter flow rate

Uniformity of emitter flow rate along the lateral line was expressed by Christiansen uniformity coefficient (CU). The uniformity of emitter flow rate at the beginning and end of the growing seasons as affected by irrigation system, water source and nitrogen dose are illustrated in Fig. (4). The statistical analysis referred to high significant effect of two factors (main and sub main) (R^2 = 0.985) on the uniformity of emitter flow rate at end of growing seasons at significance level 0.05. Drip irrigation system achieved uniformity higher than microsprinkler. The highest uniformity at end of growing seasons was achieved by (TW + 100% N) treatments for both irrigation systems; it was 87 % under "D" system and 84 % under "MS" system. The lowest uniformity was obtained by (DF+ 100% N) treatments; it was 79 % under "D" system and 76 % under "MS" system. The uniformity of emitter flow rate at end of growing season for both irrigation systems affected by "DF" more than "TW", this is may be caused by organic sediments in fish water which cause clogging in emitters and increase the variance in flow rate along the lateral lines. Increasing nitrogen dose decreased uniformity of emitter flow rate for both irrigation systems. The reduction in uniformity affected by "D" system more than "MS" system because of the orifice diameter for micro-sprinklers was wider than it for drippers and less affected by organic sediments in fish water. The reduction in uniformity of emitter flow rate under "D" system at end of growing season comparing with it at the beginning was (TW + 100 % N = 3.3 %, DF + 40 % N = 6.7 %, DF + 70 % N = 10.0 % and DF + 100 % N = 12.2 %); while under "MS" system it was (TW + 100 % N = 2.3 %, DF + 40 % N = 5.8 %, DF + 70 % N = 10.5 % and DF + 100 % N = 11.6 %).

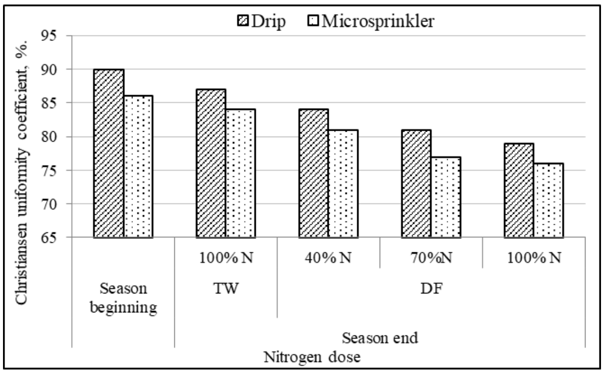

Fig. 4. Effect of water source and nitrogen dose on uniformity of emitter flow rate at two irrigation systems.

3. Total cabbage head yield and head diameter:

a. Total cabbage head yield

Total cabbage head yield was significantly affected by two factors (main and sub main) and their interaction (R^2 = 0.99) at significance level 0.05. The statistical analysis showed that; "D" system had highest effect on total cabbage head yield comparing with "MS" system, for sub main factor (water source and nitrogen dose) total cabbage head yield affected by different treatments as fallow (DF + 100% N) > (DF + 70% N)> (TW + 100% N)> (DF + 40% N). The impact of study variables on total cabbage head yield was explained by Fig. (5). "DF" increased total cabbage head yield comparing with "TW" this result can be attributed to increase nitrogen components (Ammonia, Nitrite and Nitrate) in "DF", this helps in the presence of a permanent source of nitrogen throughout the growing season, this is consistent with the nature of the growth of leafy vegetable crops. Increasing nitrogen dose increased total head yield for two irrigation system, this is may be due to increase concentration of ammonium nitrate in the root zone by increasing nitrogen dose. The difference in total head yield between traditional treatment (TW + 100% N) and other treatments were (DF + 40% N = -10.8 %, DF + 70% N = 8.1 % and DF + 100% N = 74.6 %) under "D" system and it were (DF + 40% N = -8.7 %, DF + 70% N = 20.0 % and DF + 100% N = 58.9 %) under "MS" system. "D" system increased total head yield comparing with "MS" system, this result can be interpreted as increasing growing season under "D" system increased layers of internal leaves and thus increased the total head weight.

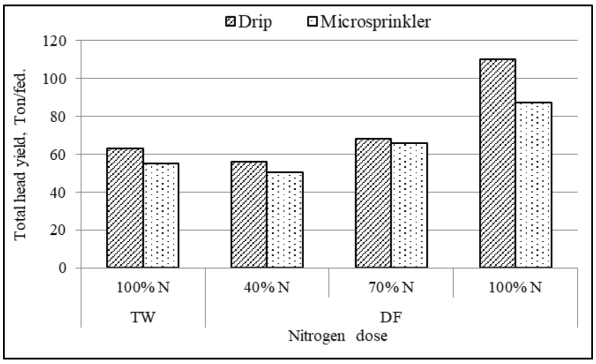

Fig. 5. Effect of water source and nitrogen dose on total cabbage head yield at two irrigation systems.

b. Cabbage head diameter

The effect of irrigation system, water source and nitrogen dose on cabbage head diameter (cm) was listed in table (5). The results indicated that; for water source and nitrogen dose, cabbage head diameter had the same trend as total head yield. "DF" increased head diameter comparing with "TW" for both irrigation systems. "MS" system increased head diameter than "D" system by about: (TW + 100% N) = 1.6%, (DF + 40% N) = 15.5%, (DF + 70% N) = 10.8% and (DF + 100% N) = 5.3%. This result can be attributed to that, "MS" system reduced the negative impact of high temperature this encouraged the head to grow by creating suitable climate for growth. In other words, sprinkler system produced cabbage head larger in size but less in weight because of less the number of internal leaves.

Table 5. Effect of water source and nitrogen dose on cabbage head diameter at two irrigation systems.

Irrigation	TW	DF		
system	100% N	40% N	70% N	100% N
Drip "D"	18.9	14.8	22.3	26.3
Microsprinkler "MS"	19.2	17.1	24.7	27.7

4. Water productivity (WP):

The relation between water productivity and study variables (irrigation system, water source and nitrogen dose) are illustrated in Fig. (6). Analysis of variance referred to high significant effect of sub main factor and the interaction (R^2 = 0.997) on water productivity at significance level 0.05. The highest value of water productivity achieved by (DF + 100% N) treatment for both irrigation systems, where it was 49.7 kg/m^3 under "D" system and 44.7 kg/m^3 under "MS" system. The lowest value obtained by (DF + 40% N) treatment which produced 25.4 kg/m^3 under "D" system and 25.7 kg/m^3 under "MS" system. Water productivity increased at "DF" comparing with "TW" where total yield increased. Water productivity had the same values nearly for two irrigation systems at every treatment (TW+ 100% N) and (DF+ 40% N). At (DF+ 70% N) treatments "MS" increased water productivity by about 9.7 %, in contrast with (DF+ 100% N) treatment where "MS" decreased water productivity by about 10.1 %.

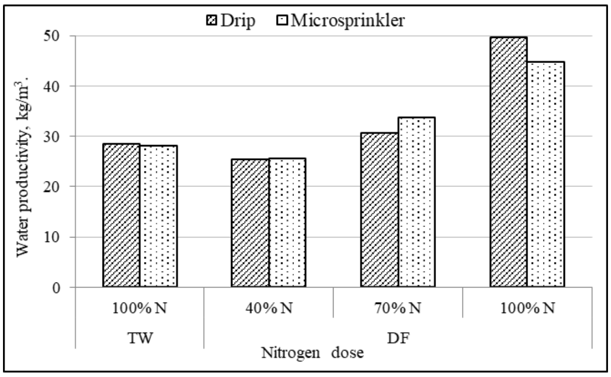

Fig. 6. Effect of water source and nitrogen dose on water productivity at two irrigation systems.

5. Nitrogen productivity (NP):

The relation between nitrogen productivity and study variables (irrigation system, water source and nitrogen dose) are illustrated in Fig. (7). The statistical analysis showed high significant effect of two factors (main and sub main) and their interaction (R^2 = 0.99) on nitrogen productivity at significance level 0.05. The highest effect on water productivity obtained by (DF + 40% N) treatment which achieved NP = 1170.8 kg_{yield}/kg_N under "D" system and 1045.8 kg_{yield}/kg_N under "MS" system. The lowest effect obtained by (TW + 100% N) treatment which produced NP = 525 kg_{yield}/kg_N under "D" system and 458.3 kg_{yield}/kg_N under "MS" system. "DF" improved nitrogen productivity comparing with "TW" by about (DF + 40% N = 123.0 %), (DF + 70% N = 54.4 %) and (DF + 100% N = 74.6 %) under "D" system and by about (DF + 40% N = 128.2 %), (DF + 70% N = 71.4 %) and (DF + 100% N = 58.9 %) under "MS" system. Raising nitrogen productivity for (DF + 40% N) treatment comparing to other treatments may be due to an increase in nitrogen dose from 40 to 100% N was not matched by a commensurate increase in cabbage head yield

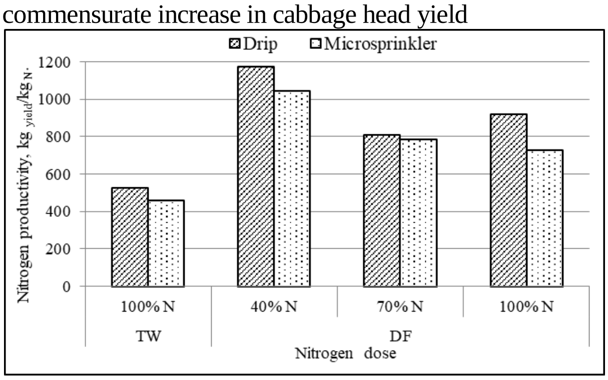

Fig. 7. Effect of water source and nitrogen dose on nitrogen productivity at different irrigation systems.

CONCLUSION

Drainage of fish ponds considers an organic and clean source for irrigation. It is suitable for vegetable crops especially leaf vegetable crops where improved the yield and productivity of water and nitrogen. Drainage of fish ponds raised cabbage head yield compared to traditional irrigation water by about 74.6 and 58.9 % under drip and microsprinkler irrigation systems respectively. However it causes problems in irrigation system especially drip system where increase the reduction in emitter flow rate and uniformity, this requires attention to the filtration system to overcome this problems. Microsprinkler less affected by drainage of fish ponds, moreover it accelerate growing season where it decreases growing season by about 20 days, this mean saving irrigation water and growing time.

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تأثير مصدر ماء الري على آداء نظم الري الدقيق وانتاجية محاصيل الخضر الورقية

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تهدف هذه الدراسة الى تقييم تأثير استخدام ماء صرف المزارع السمكية على آداء نظم الري الدقيقة وإنتاجية محاصيل الخضار الورقي (الكرنب الصيفي). تم اجراء تجارب حقلية خلال موسم الصيف لعامي 2019 و 2020 بالمزرعة البحثية لقسم البساتين بكلية الزراعة جامعة كفر الشيخ بشمال الدلتا والتي تتصف تربتها بالقوام الطيني. تتضمنت متغيرات الدراسة التالي : نظامان للري الدقيق (الرش الدقيق - التنقيط) ، مصدران لماء الري (ماء الري التقليدي – ماء صرف المزارع السمكية) ، ثلاث نسب من جرعة السماد الآزوتي الموصى بها (100٪ن، 70٪ن ، 40٪ن) والتي تم تطبيقها على ماء صرف المزارع السمكية فقط بينما مع ماء الري تم تطبيق نسبة السماد الموصى بها كاملة (100٪). أشارت النتائج للآتي: استخدام ماء صرف السمك زاد من نسبة الانخفاض في تصرف النقاطات والرشاشات في نهاية الموسم مقارنة بماء الري التقليدي. أقل انخفاض في التصرف كان مع المعاملة (ماء الري التقليدي + 100٪ن) بنسبة 6.1٪ لنظام التنقيط و 3.0٪ لنظام الرش الدقيق. أفضل قيمة للانتظامية على طول الخط الحقلي في نهاية موسم النمو مقارنة بالانتظامية في بداية الموسم تم الحصول عليها مع (ماء الري التقليدي + 100٪ن) كانت بنسبة 87.0 ٪ للتنقيط و 84.0 ٪ للرش الدقيق. نظام الري بالتنقيط اعطى الانتاجية الاعلى وزنا بينما نظام الري بالرش الدقيق انتج رؤوس ذات القطر الاكبر. الانتاجية الاعلى تم الحصول عليها مع المعاملة (ماء صرف السمك + 100٪ن) حيث كانت الانتاجية 110 طن /فدان للتنقيط و 87.4 طن/فدان للرش الدقيق. ماء صرف السمك اعطي القيم الاعلى لكلا من إنتاجية الماء والنيتروجين حيث اعطت المعاملة (ماء صرف السمك + 100٪ن) اعلى قيمة لانتاجية الماء فقد كانت 49.7كجم/م^3 للتنقيط و 44.7كجم/م^3 للرش الدقيق، بينما اعطت المعاملة (ماء صرف السمك + 40٪ن) اعلى قيمة لانتاجية النيتروجين حيث كانت 1170.8كجم$_{محصول}$/كجم$_{ن}$ للتنقيط و 1045.8 كجم $_{محصول}$/كجم$_{ن}$ للرش الدقيق .