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SUSTAINABLE AGRICULTURE OF WHEAT USING LOW-QUALITY WATER: ASSESSING NUTRIENT UPTAKE, HEAVY METALS ACCUMULATION, AND YIELD PRODUCTIVITY

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ABSTRACT: A field experiment was conducted to assess the potential use of low-quality water for irrigation and its effect on nutrients uptake, heavy metals accumulation, yield productivity and grains yield efficiency of wheat plant. Irrigation water sources were Nile water, mixture of Nile water + Agricultural drainage water, Agricultural drainage water, and sewage water. Obtained results proved that irrigation with low-quality water would accumulate appreciable amounts of heavy metals in soil which are toxic to plant, but this accumulation was more pronounced in the straw compared with grains. The macronutrients uptake of straw under irrigation with Nile water, Nile water + Agricultural drainage water, Agricultural drainage water, and sewage water were 16.05, 20.28, 21.20 and 26.79 g kg^{-1}, respectively for N; 2.17, 2.73, 4.22 and 4.86, respectively for P; 9.01, 12.53, 17.31 and 19.05 g kg^{-1}, respectively for K. The macronutrients uptake of grains was 32.08, 38.75, 39.82 and 40.51 g kg^{-1}, respectively for N; 3.72, 4.15, 5.43 and 6.25, respectively for P; 14.77, 16.53, 25.11 and 27.17 g kg^{-1}, respectively for K. The micronutrients uptake of straw under irrigation with Nile water, Nile water + Agricultural drainage water, Agricultural drainage water, and sewage water were 130.5, 194.2, 227.3 and 253.7 g kg^{-1}, respectively for Fe; 78.3, 119.7, 148.2 and 155.8, respectively for Mn; 25.5, 38.4, 43.8 and 54.3 g kg^{-1}, respectively for Zn. The micronutrients uptake of grains was 74.5, 101.3, 117.2 and 124.5 g kg^{-1}, respectively for Fe; 49.2, 68.3, 79.1 and 112.7, respectively for Mn; 16.1, 21.3, 23.7 and 31.5 g kg^{-1}, respectively for Zn. The heavy metals content of straw under irrigation with Nile water, Agricultural drainage water, Nile water + Agricultural drainage water and sewage water were 10.13, 15.72, 17.55 and 24.31 g kg^{-1}, respectively for Pb; 7.30, 13.81, 15.47 and 18.22, respectively for Ni; 5.02, 8.53, 9.71 and 12.37 g kg^{-1}, respectively for Cd. The heavy metals content of grains under irrigation with Nile water, Agricultural drainage water, Nile water + Agricultural drainage water and sewage water were 7.51, 10.32, 12.28 and 17.45 g kg^{-1}, respectively for Pb; 5.43, 8.31, 9.75 and 12.52, respectively for Ni; 2.17, 3.53, 4.15 and 5.21 g kg^{-1}, respectively for Cd. The straw yield under irrigation with Nile water, Agricultural drainage water, Nile water + Agricultural drainage water, and sewage water were 3.185, 2.775, 1.852 and 2.253 g kg^{-1}, respectively, while the grains yield was 2.751, 1.957, 1.135 and 1.541 g kg^{-1}, respectively.

Key words: Wheat, water quality, heavy metals, productivity.

INTRODUCTION

Despite the fact that the wheat (*Triticum aestivum* cv.) is considered the primary grains crop in Egypt, the supplementing production of wheat has been achieved by importing just over half of its needs to satisfy the annual demands **(El-Habbasha and El-Sayed, 2020)**.

Irrigation water quality is critical for proper management necessary for sustainable agriculture. Thus, there may be a need to use some low-quality water such as agricultural

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drainage or **sewage** waters for irrigation **(Qadir *et al.*, 2010)**.

Expanding the cultivation of wheat with irrigation from diverse sources including waters of lower quality is significantly important. Usage of some low-quality waters such as Agricultural drainage and sewage waters for irrigation would accumulate appreciable amounts of heavy metals in soil which are toxic to plant. This bio accumulation is a major dangerous environmental health problem **(Qadir *et al.*, 2010)**. The pollution resulting from heavy metals accumulation deteriorate the quality of the food crops and water in addition to threatening the health of animals and human **(Dong *et al.*, 2011)**.

Therefore, it is important to study how pollution affects plants because it not only affects the economy by decreasing crop yields but also harms human and animal health.

MATERIALS AND METHODS

A field experiment was conducted at four locations different in their irrigation water source at Sahl El-Husaineya research stations, Agriculture Research Center, Sharkia Governorate. Irrigation water sources were Nile water from Sarhan canal, mixture of Nile water+Agricultural drainage water from El-Salam canal, Agricultural drainage water from Bahr Hadous and sewage water from Bahr El-Baqar.

Wheat plant (*Triticum aestivum cv.*) was cultivated during the growing season of 2017 ~ 2018 to assess the potential use of low-quality water for irrigation and its effects on plant pollution, yield productivity, and grains yield efficiency.

The physical and chemical properties of soils are shown in Tables 1, 2 and 3. The chemical characteristics of different irrigation water sources are shown in Tables 4 and 5.

Recommended doses of nitrogen, phosphorus and potassium were added. Nitrogen as ammonium nitrate, Phosphorus as super phosphate calcium and Potassium as potassium sulphate were added at rates of 100 kg N fed $^{-1}$, 13.5 Kg P fed^{-1} and 40 kg K_2 fed^{-1}, respectively.

Plant samples were collected at harvest corresponding to 120 days from sowing. The macronutrients (N, P and K), micronutrients (Fe, Mn, and Zn) and heavy metals (pb, Ni, and Cd) were determined after wet digestion of plant samples.

Methods of Analysis

Soil analysis

Particle size distribution was conducted using international pipette methods according to **Gee and Bauder (1986)**. The calcium meter method described **by Klute (1986)** was used to determine total calcium carbonate (CaCO3 gkg^{-1}). Organic matter was determined using the method of Walkely and Blank as described by **Jackson (1973).** Electrical conductivity (ECe) and pH as well as Soluble cations and anions were determined in soilpaste extract using stander methods described by **Jackson (1973).** Available nitrogen was determined by stem-distillation procedure using MgO-Devarda alloy according to Bremner and Keency methods as described by **Black *et al.* (1982).** Available phosphorus was extracted by 0.5 M $NaHCO_3$ at PH 8.5 and determined calorimetrically using the ascorbic acid method described by **Watanabe and Olsen (1965).** Available potassium was extracted by 1.0 M ammonium acetate at PH 7.0 and determined by the flam Photometer according to **Jackson (1973)**. Available macronutrients (N, P and K) and micronutrients (Fe, Zn, Cu and Mn) as well as extractable heavy metals (Ni, Cd and pb) were determined according to **Soltonpour (1985).** Irrigation water analysis: Electrical conductivity " ECe" and PH as well as soluble cations and anions were determined according to the standard methods described by **Page *et al.* (1982).** Soluble (Fe, Mn, Zn, Cu, pb, Ni and Cd) were determined by inductively coupled plasma (ICP) spectrometry according to **Soltonpoure (1985)**.

Plant analysis: Plant samples were collected at harvest and extracted by digestion with H_2SO_4 + $HCLO_4$ to determine macronutrients (N, P and K), micronutrients (Fe, Mn, Zn and Cu) and heavy metals (pb, Ni, and Cd) according to **Chapman and Pratt (1964)**.

Table 1. Physical analysis of soil at different locations used for the current study

Location and Irrigation water source	Soil particle distribution (%)					O.M (gkg^{-1})	$CaCO_3$ (gkg^{-1})
	Sand		Silt	Clay	Texture		
	Course	Fine					
El-Husaineya region Nile water	2.95	28.93	32.80	35.32	Clay loam	15.3	52.5
El- Rowad village Nile water + Agricultural drainage water	3.82	25.50	33.36	37.32	Clay loam	15.7	58.2
Hadous region Agricultural drainage water	1.85	20.56	35.85	41.74	Clay loam	16.2	63.0
Tariq bin Ziyad village Sewage water	4.75	22.90	30.18	42.17	Clay loam	17.5	72.1

Table 2. Chemical analysis of soil at different locations used for the current study

Location and Irrigation water Source	pH *	EC ** (dsm^{-1})	Cation (mmole L^{-1})				Anion (mmole L^{-1})			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	CO_3^{2-}	SO_4^{2-}
El-Husaineya region Nile water	7.88	1.88	4.15	2.18	13.86	0.61	1.77	8.53	nil	10.50
El Rowad village Nile water + Agricultural drainage water	7.83	4.38	7.43	11.54	29.21	0.64	4.67	23.82	nil	20.33
Hadous region Agricultural drainage water	7.75	5.87	10.50	14.75	35.86	0.73	6.21	29.31	nil	26.32
Tariq bin Ziyad village Sewage water	7.78	5.23	9.85	13.15	32.62	0.68	5.65	27.44	nil	23.21

* Soil-water suspension (1:5) ** Soil paste extract

Table 3. Concentration of macro and micronutrients as well as accumulation of heavy metals in soil at different locations used for the current study

Location and irrigation water source	Macronutrient ($mg\ kg^{-1}$)			Micronutrient ($mg\ kg^{-1}$)				Heavy metal ($mg\ kg^{-1}$)		
	N	P	K	Fe	Mn	Zn	Cu	Pb	Ni	Cd
El-Husaineya region Nile water	55.30	17.48	45.01	2.35	1.18	0.75	0.25	1.20	0.45	nil
El- Rawad village Nile water + Agricultural drainage water	56.42	16.32	47.32	2.48	1.58	0.90	0.34	3.75	0.66	0.02
Hadous region Agricultural drainage Water	57.38	17.84	48.26	2.55	1.77	0.93	0.44	5.63	0.77	0.03
Tariq bin Ziyad village Sewage water	58.72	18.55	52.38	2.89	1.83	0.95	0.52	7.75	0.82	0.03

Table 4. Some chemical analysis of different irrigation water sources used for the current study

Irrigation water Source	pH	EC (dsm^{-1})	Cation ($mmole\ L^{-1}$)				Anion ($mmole\ L^{-1}$)			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	CO_3^{2-}	SO_4^{2-}
Nile water (Sarhan Canal)	7.82	1.36	3.68	1.98	5.65	0.89	1.36	4.49	nil	6.35
Nile water + Agricultural drainage water (El-Salam Canal)	7.95	1.48	2.89	4.61	5.58	0.82	1.66	4.31	nil	7.93
Agricultural drainage water (Bahr Hadous)	8.10	1.59	3.18	3.95	6.98	1.09	2.13	4.90	nil	8.17
Sewage water (Bahr El-Baqar)	8.23	1.75	4.22	3.21	7.85	1.12	2.54	4.19	nil	9.67

Table 5. Concentration of macro and micronutrients as well as heavy metals of irrigation water sources used for the current study

Irrigation water source	Macronutrient ($mg L^{-1}$)			Micronutrient ($\mu g L^{-1}$)				Heavy metal ($\mu g L^{-1}$)		
	N	P	K	Fe	Mn	Zn	Cu	Pb	Ni	Cd
Nile water (Sarhan Canal)	17.62	3.27	7.13	760	425	630	40	370	20	150
Nile water + Agricultural drainage water (El-Salam Canal)	21.14	4.01	7.95	925	440	660	70	625	33	250
Agricultural drainage water (Bahr Hadous)	31.30	4.43	8.02	1170	515	740	90	715	50	450
Sewage water (Bahr El-Baqar)	33.41	5.28	8.23	1480	675	890	100	1130	67	650

RESULTS AND DISCUSSION

Effect of Using Low-Qualiity Water for Irrgation on Wheat Plant

Macronutrients uptake by wheat plants as affected by different irrigation water sources

Macronutrients uptake of wheat straw

Contents of macronutrients in wheat straw influenced by different irrigation water sources are identified in Table 6. Data shows that the plants irrigated with sewage water gave the highest N uptake of 26.79 kg fed^{-1} compared to 16.05, 20.28 and 21.20 kg fed^{-1} under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. As for P uptake, the highest value of 4.86 kg fed^{-1} was observed under irrigation with sewage water compared to 2.17, 2.73 and 4.22 kg fed^{-1} under the irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. Regarding K uptake, Data proved that the highest value of 19.05 kg fed^{-1} was observed under irrigation with sewage water compared to 9.01, 12.53 and 17.31 kg fed^{-1} for plants irrigated with, Nile water, Nile water + Agricultural drainage water, Agricultural drainage water, respectively. In this regard**, Abd-El-Kader (2007)** found that nitrogen uptake by wheat was highly influenced by the application of sewage water. **Sallam *et al.* (2008)** found that the highest values of N, P and K concentration in plants were recorded upon irrigation with Bahr El-Baqer drainage water. **Mostafa *et al.* (2015)** reported that the content of macronutrients in wheat straw under irrigation with Nile water, Agricultural drainage water, Nile water + Agricultural drainage water and sewage water was 10.2, 12.1, 11.1 and 14.6 g kg^{-1}, respectively for N; 2.7, 3.4, 3.1 and 3.95, respectively for P; 28.1, 31.3, 28.9 and 35.6 g kg^{-1}, respectively for K.

Macronutrients uptake of wheat grains

Contents of macronutrients grains influenced by different water sources are identified in Table 6. Data show that the plants irrigated with sewage water gave the highest N uptake of 40.51 kg fed^{-1} compared to 32.08, 38.75 and 39.82 kg fed^{-1} for plants irrigated with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water respectively. As for P uptake, data proved that the highest P uptake of 6.25 Kg fed^{-1} was under the irrigation with sewage water compared to 3.72, 4.15 and 5.43 kg fed^{-1} for plants irrigated with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively.

Table 6. Macronutrients uptake of wheat straw and grains as affected by different irrigation water sources

Irrigation water source	Wheat straw ($kg\ fed^{-1}$)			Wheat grains ($kg\ fed^{-1}$)		
	N	P	K	N	P	K
Nile water (Sarhan Canal)	16.05	2.17	9.01	32.08	3.72	14.77
Nile water + Agricultural drainage water (El-Salam Canal)	20.28	2.73	12.53	38.75	4.15	16.53
Agricultural drainage Water (Bahr Hadous)	21.20	4.22	17.31	39.82	5.43	25.11
Sewage water (Bahr El-Baqar)	26.79	4.86	19.05	40.51	6.25	27.17

Concerning K uptake, data show that the highest value of 27.17 kg fed^{-1} was observed under irrigated with Nile water compared to 14.77, 16.53 and 25.11 kg fed^{-1} for under irrigation with Nile water + Agricultural drainage water, Agricultural drainage water and sewage water, respectively. In this regard, **Shaban (1998)** found that the content of macronutrients in grains under the irrigation with Nil water, Nil water + Agricultural drainage water, Agricultural drainage water, and sewage water were 114.2, 61.9, 72.4 and 183.5 mg $plant^{-1}$, respectively for N; 13.1, 6.45, 8.7 and 13, respectively for P; 22.1, 13.1, 16.9, and 22.7 mg/plant , respectively for K. **Rehan et al. (2004)** who found that the N, P and K concentration and uptake of grains increased with irrigation with sewage water. **Mohammad *et al.* (2010)** showed that the concentrations of N, P and K in plants were significantly increased by irrigation with waste water in long growing season. **Mostafa *et al.* (2015)** reported that the content of macronutrients in grains under the irrigation with Nile water, Agricultural drainage water, Nile water + Agricultural drainage water and sewage water were 19.1, 21.4, 20.8 and 22.0 g kg^{-1}, respectively for N; 3.9, 4.5, 4.35 and 4.6 g kg^{-1}, respectively for P; 23.3, 25, 24.7 and 25.5 g kg^{-1}, respectively for K.

Micronutrients uptake by wheat plants as affected by different irrigation water sources

Micronutrients uptake of wheat straw

The content of micronutrients in wheat straw under irrigation with different water sources are identified in Table 7. Data proved that the uptake of micronutrients in plants irrigated with sewage water gave the highest Fe uptake of 253.7 g fed^{-1} compared to 130.5, 194.2, and 227.3 g fed^{-1}, respectively under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. Data also reveals that the highest Mn uptake of 155.8 g fed^{-1} observed under irrigation with sewage water compared to 78.3, 119.7, 148.2 g fed^{-1} under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. Concerning Zn uptake, data indicated that the highest of 54.3 g fed^{-1} was observed under irrigation with sewage water compared to 25.5, and 38.4 and 43.8 g fed^{-1} under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. In this regard, **El-Gazzar (1996)** found that the content of Fe, Mn and Zn increased in the plants irrigated with polluted water and reached 213, 60 and 18 mg kg^{-1} respectively, compared to those irrigated with

Table 7. Micronutrients uptake of wheat straw and grains as affected by different irrigation water sources

Irrigation water source	Wheat straw ($g\ fed^{-1}$)			Wheat grains ($g\ fed^{-1}$)		
	Fe	Mn	Zn	Fe	Mn	Zn
Nile water (Sarhan Canal)	130.5	78.3	25.5	74.5	49.2	16.1
Nile water + Agricultural drainage water (El-Salam Canal)	194.2	119.7	38.4	101.3	68.3	21.3
Agricultural drainage water (Bahr Hadous)	227.3	148.2	43.8	117.2	79.1	23.7
Sewage water (Bahr El-Baqar)	253.7	155.8	54.3	124.5	112.7	31.5

Nile waters which contained lower values of 167 mg kg^{-1} for Fe; 60 $mgkg^{-1}$ for Mn; 48 mg kg^{-1} for Zn, with increasing rates of 27.54%., 33.33% and 77.08% for Fe, Mn and Zn, respectively. **El-Mowelhi *et al.* (2001)** proved that irrigation with waste water and Agricultural drainage water increased element concentration in the different crops. **Shaban (2005)** reported that the uptake values of Fe, Mn and Zn, in straw of wheat plant increased under irrigation with sewage water of Bahr El-Baqer drain. **Abo-Rabeh (2011)** reported that the irrigation water quality affects the distribution and accumulation of Zn and Mn in root, stem and leaves of plants at the harvest time. **Fabiola *et al.* (2012)** reported that the contents of Zn and Mn in shoots of plants increased significantly owing to the application of sewage effluent. **Yasser *et al.* (2013)** found that Fe, Mn and Zn concentration ranged between 79.4 to 128.41; 44.03 to 55.6 and 50.8 to 83.48 mg kg, respectively for plant treated waste water.

Micronutrients uptake of wheat grains

Content of micronutrients Fe, Mn and Zn in grains under irrigated with different water sources are identified in Table 7. Data shows that the plants after irrigation with sewage water gave the highest Fe uptake of 124.5 g fed^{-1} compared to 74.5, 101.3, and 117.2 g fed^{-1} under the irrigation with, Nile water, Nile water + Agricultural drainage water, and Agricultural drainage water respectively. Also, data indicated that the highest Mn uptake of 112.7 g fed^{-1} was observed under irrigation with sewage water compared to 49.2, 68.3, and 79.1 g fed^{-1} under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively.

As for Zn uptake, data proved that the highest Zn uptake of 31.5 g fed^{-1} was observed under irrigation with sewage water compared to 16.1, 21.3, 23.7 g fed^{-1} for under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. In this respect, **MacNicol and Beckett (1985)** reported that the critical level of Cd in grains of wheat Plant ranged between 5 to 10 mg kg^{-1}. **Mostafa (2001)** reported that the values of micro nutrient concentration under irrigation with Nile water, Agricultural drainage water and sewage water were 241, 349, and 537 mg kg^{-1}, respectively for Fe; 24.3, 31.6, and 38.6 mg kg^{-1}, respectively for Mn; 21.3, 38.0 and 53.2 mg kg^{-1} respectively for Zn. **Shaban (2005)** revealed that the uptake values of Fe, Mn and Zn in grains increased with irrigation with sewage water of Bahr El-Baker drain. **Mussarat *et al.* (2021)** investigated the effect of using low quality water for irrigation and found that the plants irrigated with waste water contained high Zn and Mn in grains compared to those irrigated by ground water.

Heavy metals accumulation in wheat plants as affected by different irrigation water sources

Heavy metals accumulate in wheat straw

Accumulation of heavy metals Pb, Ni, Cd in straw under irrigated with different water sources are identified in Table 8. Data proved that the content of plants heavy metals after irrigation with sewage water gave the highest Pb content of 24.31 g fed^{-1} compared to 10.13, 15.72 and 17.55 g fed^{-1}, respectively under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. Data also reveals that the highest Ni content of 18.22 g fed^{-1} observed under irrigation with sewage water compared to 7.30, 13.81 and 15.47 g fed^{-1} under irrigation with Nile water, Nile water+ Agricultural drainage water and Agricultural drainage water, respectively. Concerning Cd content, data indicated that the highest of 12.37 g fed^{-1} was observed under irrigation with sewage water compared to 5.02, 8.53, 9.71 g fed^{-1} under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. In this regard, **Aboul-Ross *et al.* (1996)** found that concentrations of Cd in corn leaves ranged from 0.012 to 0.13 mg kg^{-1}. The Cd content of leaf samples was within normal concentration rang of < 0.3 mg kg^{-1} being about one third that in leaves. **Mostafa *et al.* (2000)** found that the concentration of Ni in wheat straw under the irrigation with Nile water, Agricultural drainage water and sewage water were 4.17, 5.52 and 11.4 mg kg, respectively. these contents exceeding the intermediate level of 0.14 mg kg^{1} suggested by **Chapman (1964)**. **Shaban (2005)** reported that the content of Pb in straw increased with using sewage water of Bahr El-Baker drainage for irrigation. **Mohammed and Hamid (2012)** noticed that total concentrations of Pb in plants irrigated with raw sewage effluent was significantly higher than those irrigated with 50% diluted sewage effluent. The plants irrigated with well water gave the lowest concentrations.

Heavy metals accumulation in wheat grains

Accumulation of heavy metals i.e., Pb, Ni, Cd in grains under irrigated with different water sources are identified in Table 8. Data shows that the content of heavy metals in plants irrigated with sewage water gave the highest Pb content of 17.45 g fed^{-1} compared to 7.51, 10.32 and 12.28 g fed^{-1} under the irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. Also, data indicated that the highest Ni uptake of 12.52 g fed^{-1} was observed under irrigation with sewage water compared to 5.43, 8.31 and 9.75 g fed^{-1} under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. As for Zn uptake, data proved that the highest Cd uptake of 5.21 g fed^{-1} was observed under irrigation with sewage water compared to 2.17, 3.53 and 4.15 g fed^{-1} for under irrigation with Nile water, Nile water + Agricultural drainage water and Agricultural drainage water, respectively. In this respect, **VanLandschoot *et al.* (1984)** reported that the toxic level for Pb in grains of wheat Plant ranged between 30 and 50 mg kg^{-1}. **MacNicol and Beckett (1985)** reported that Ni critical level of wheat grains ranged from 10 to 60 mg kg^{-1}. **Mussarat *et al.* (2021)** found that wheat plants irrigated with waste water contained high Cd in their grains compared to those irrigated by ground water.

Yield productivity and efficiency of grains yield production of wheat plants as affected by different irrigation water sources

Yield of wheat straw

Straw yield of wheat influenced by different irrigation water sources are identified in Table 9. Data shows that the plants irrigated with Nile water gave the highest straw yield of 3.185 Mg fed^{-1} compared to 2.775, 2.253 and 1.852 Mg fed^{-1} under irrigation with Nile water + Agricultural drainage water, sewage water, Agricultural drainage water, respectively. In this respect, **Aziz *et al.* (1995)** showed that the sewage waste water raised the yield parameters of four wheat cultivate. This may be due the beneficial effect of suspended organic matter and nutrients that were prevailing in such these water qualities. **Shaban (1998)** found that the highest wheat straw yield of 9.36 kg/plot was under irrigated with sewage water compared to 6.05, 5.52 and 6.84 kg/plot for plants irrigated with Nile water, Nile water + Agricultural drainage water, and Agricultural drainage water respectively.

Table 8. Heavy metals accumulation (g fed^{-1}) of wheat straw and grains as affected by different irrigation water sources

Irrigation water source	Wheat straw (g fed^{-1})			Wheat grains (g fed^{-1})		
	Pb	**Ni**	**Cd**	**Pb**	**Ni**	**Cd**
Nile water (Sarhan Canal)	10.13	7.30	5.02	7.51	5.43	2.17
Nile water + Agricultural drainage water (El-Salam Canal)	15.72	13.81	8.53	10.32	8.31	3.53
Agricultural drainage water (Bahr Hadous)	17.55	15.47	9.71	12.28	9.75	4.15
Sewage water (Bahr El-Baqar)	24.31	18.22	12.37	17.45	12.52	5.21

Table 9. Straw and grain yields and grains yield efficiency of wheat as affected by different irrigation water sources

Irrigation water source	Straw and grains dray matter (Mg fed^{-1})		Efficiency of grains yield production (%) *
	Straw	**Grains**	
Nile water (Sarhan Canal)	3.185	2.751	46.34
Nile water + Agricultural drainage water (El-Salam Canal)	2.775	1.957	41.36
Agricultural drainage Water (Bahr Hadous)	1.852	1.135	38.00
Sewage water (Bahr El-Baqar)	2.253	1.541	40.62

***** Equals to (Grains Yield / Grains yield + Straw yield) x 100

Mostafa *et al.* (2000) detected that the highest straw yield was identified when plantes irrigated with sewage water compared to other irrigation waters. This may be related to the higher contents of plant nutrients, particularly N. **Mostafa (2001)** mentioned that the plant irrigated with Nile water gave straw yield of 2.29 Mg fed^{-1} compared to 2.26 and 2.31 Mg fed^{-1} for those irrigated with agricultural drainage water and sewage waters respectively.

Yield of wheat grains

Grains yield of wheat influenced by different irrigation water sources are identified in Table 9. Data shows that the highest grains yield of 2.751 Mg fed^{-1} was observed under irrigation with Nile water, compared to 1.957, 1.541and 1.135 Mg fed^{-1} under irrigation with Nile water + derange water, sewage water, and derange water, respectively. In this regard, **Amany *et al.* (2008)** found that the grain yield was significantly affected by the sources of irrigation water in the two seasons. El-Salam canal irrigation water produced the highest grains yield of 2.0 and 1.98 $Mgfed^{-1}$ in two seasons respectively. **Saleh *et al.* (2013)** identified that heavy metal concentration in plants may be increased due to either higher amounts or to the opposite of the dilution effect phenomenon, where the dry matter yield of the plants diminished with increasing the concentration of the applied wastes. **Mostafa *et al.* (2015)** found that the highest grains yield of 2.35 Mg fed^{-1} was observed under irrigation with Nile water, compared to 1.62, 1.79 and 1.60 Mg fed^{-1} under irrigation with Agricultural drainage water, Nile water + Agricultural drainage water and sewage water, respectively.

Efficiency of grains yield production

Efficiency of grains yield production of wheat influenced by different irrigation water sources are identified in Table 9. Data shows that the highest efficiency of grains yield production of 46.34% was observed under irrigation with Nile water, compared to 41.36, 40.62, and 38.00%, under irrigation with Nile water + Agricultural drainage water, sewage water, and Agricultural drainage water, respectively.

Yield components of wheat

Yield components of wheat; Plant height, Spike length, spike weight and grains number influenced by different irrigation water sources are identified in Table 10 data shows that plants irrigated with sewage water gave the highest plant height of 79.20 cm compared to 77.51, 71.45 and 58.17 cm under irrigation with Nile water, Nile water + Agricultural drainage water, Agricultural drainage water respectively. Data proved that the highest spike length of 13.45 was observed under irrigation with sewage water compared to 12.42, 10.37 and 9.75 cm under Nile water, Nile water + Agricultural drainage water, Agricultural drainage water respectively, respectively. Data proved that the highest spike weight of 2.41 ton fed^{-1} observed under irrigation with Nile water compared to 1.77, 1.45 and 1.28 ton fed^{-1} under irrigation with Nile water + Agricultural drainage water, sewage water, Agricultural drainage water, respectively. As for grains number, data reveal that the highest grains number of 37.55 was observed under irrigation with Nile water compared to 35.12, 31.12 and 28.43 under irrigation with, Nile water + Agricultural drainage water, sewage water, and Agricultural drainage water, respectively. In this respect, **Amany *et al.* (2008)** found that plant height and spike length were significantly affected by sources of irrigation water. The highest plant height of 91.83 and 86.16 cm were observed under irrigation with Bahr-Hadous and Bahr El-Baqar, respectively. **Mostafa *et al.* (2015)** reported that the plants irrigated with Nile water gave highest plant height of 82.5 cm compared to 66.7, 70.8 and 64.4 cm for under irrigation with Agricultural drainage water, Nile water + Agricultural drainage water and sewage water, respectively. The highest spike length of 11.4 cm was obtained under irrigation with Nile water compared to 10.8, 11.3 and 9.99 cm under irrigation with Agricultural drainage water, Nile water + Agricultural drainage water and sewage water, respectively.

Table 10. Yield components of wheat as affected by different irrigation water sources

Irrigation water source	Yield Components			
	Plant height (cm)	Spike length (cm)	Spike weight (ton fed^{-1})	Grains number (Plant^{-1})
Nile water (Sarhan Canal)	77.51	12.42	2.41	37.55
Nile water + Agricultural drainage water (El-Salam Canal)	71.45	10.37	1.77	35.12
Agricultural drainage water (Bahr Hadous)	58.17	9.75	1.28	28.43
Sewage water (Bahr El-Baqar)	79.20	13.45	1.45	31.17

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الـزراعــة المســتدامة للقمح باستخدام مياه منخفضة الجــودة : تقييم امتصــاص العناصـــر الغذائيـــة، وتراكم المعادن الثقيلة، وإنتاجية المحصول

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يهدف البحث إلى دراسة إمكانية استخدام مياه منخفضة الجودة في الرى "مثل مياه الصرف الزراعى - مياه الصرف الصحى - مياه النيل مخلوطة بمياه الصرف الزراعى" وتأثير ذلك على جودة وإنتاجية محصول القمح وذلك من خلال تقدير محتوى نبات القمح من العناصر الغذائية الكبرى والصغرى والثقيلة فى القش والحبوب، بالإضافة إلى محصولى القش والحبوب، كفاءة إنتاج الحبوب ، وكذلك مكونات المحصول. أجريت تجربة حقلية خلال موسم النمو 2018/2017م فى أربع مواقع بمنطقة سهل الحسينية تختلف فى مصدر مياه الرى: (1) مياه النيل من ترعة سرحان، (2) مياه النيل خلط مع الصرف الزراعى من ترعة السلام ، (3) مياه الصرف الزراعي من بحر حادوس ، (4) مياه الصرف الصحى من بحر البقر. عند الحصاد (145 يوم من الزراعة) تم تقدير محصولى القش والحبوب، وكفاءة إنتاج الحبوب (%)، وكذلك مكونات المحصول. واخذت العينات النباتية لتجفيفها واستخلاصها وإعدادها لتقدير: العناصر الغذائية الكبرى (K- P- N)، العناصر الغذائية الصغرى (Zn - Mn - Fe)، تراكم العناصر الثقيلة (Ni - Cd -Pb). أهم النتائج المتحصل عليها: محتوى النبات من العناصر الغذائية: أعلى قيم لمحتوى القش من النيتروجين والفوسفور والبوتاسيوم (26.79، 4.86 ، 19.05 كجم فدان$^{-1}$ على التوالى) تحصل عليها عند الرى بمياه الصرف الصحى ، بينما أعلى قيم لمحتوى الحبوب من النيتروجبن والفوسفور والبوتاسيوم (40.51، 6.25 ، 27.17 كجم فدان-1 على التوالى) تحصل عليها عند الرى بمياه الصرف الصحى . أعلى قيم لمحتوى القش من الحديد والمنجنيز والزنك (253.7 ، 155,8 ، 54.3 كجم فدان$^{-1}$على التوالى) تحصل عليها عند الرى بمياه الصرف الصحى، أعلى قيم لمحتوى حبوب القمح من الحديد والمنجنيز والزنك (124.5 ، 112.7 ، 31.5 جم فدان-1على التوالى) تحصل عليها عند الرى بمياه الصرف الصحى. أعلى قيم لمحتوى القش من الرصاص والنيكل والكادميوم (24.31 ، 18,22 ، 12.37 جم فدان$^{-1}$ على التوالى) تحصل عليها عند الرى بمياه الصرف الصحى، بينما أعلى قيم لمحتوى حبوب القمح من الرصاص والنيكل والكادميوم (17,45 ، 12,52 ، 5.21 جم فدان-1على التوالى) تحصل عليها عند الرى بمياه الصرف الصحى. المحصول وجودتة ومكوناته: أعلى قيمة لمحصول قش القمح (3,185 طن فدان$^{-1}$) تحصل عليها عند الرى بمياه النيل، بينما أعلى قيمة لمحصول الحبوب (2,751 طن فدان$^{-1}$) تحصل عليها عند الرى بمياه النيل. أعلى قيمة لكفاءة إنتاج الحبوب (46.34%) تحصل عليها عند الرى بمياه الصرف النيل، بينما أقل قيمة (38.00%) تحصل عليها عند الرى بمياه الصرف الزراعى. أعلى قيمة لطول للنبات (79.20 سم) تحصل عليها عند الرى بمياه الصرف الصحى ، بينما أقل قيمة (58.17 سم) تحصل عليها عند الرى بمياه الصرف الزراعى. أعلى قيمة لوزن السنابل (2.41 طن فدان$^{-1}$) تحصل عليها عند الرى بمياه النيل ، بينما أقل قيمة (1.28 طن فدان$^{-1}$) تحصل عليها عند الرى بمياه الصرف الزراعى. أعلى قيمة لعدد الحبوب (37.55 حبة نبات$^{-1}$) تحصل عليها عند الرى بمياه النيل ، بينما أقل قيمة (28.34 حبة نبات$^{-1}$) تحصل عليها عند الرى بمياه الصرف الزراعى.

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