SVU-International Journal of Agricultural Science
Volume 3 Issue (1) pp.: 72-84, 2021
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2021.60182.1075

RESEARCH ARTICLE

Impact of nitrogen fertilizer levels of and types of irrigation water on barley yield and its attributes

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Abstract

A pot experiment was carried out at the Experimental Farm, Faculty of Agriculture, South Valley University, Qena, Egypt during the 2015-2016 and 2016-2017 seasons to study the effect of nitrogen fertilizer levels and types of irrigation water (W_1; Tap water only, W_2; manipulated wastewater with sandy filter, W_3; manipulated wastewater with nano-titanium dioxide + sandy filter and W_4; a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water) on growth, yield and its attributes of barley cv. Giza 2000. A randomized complete block design (RCBD) using a split-plot arrangement with four replications was used. The main plot was four different levels of nitrogen fertilizer and the sub-plot were four different types of irrigation water. The seeds of above mentioned variety were used in the pot experiments. The highest mean values of plant height, number of tillers plant^{-1}, spike length, number of grains spike^{-1}, spike weight, biological yield plant^{-1} and grain yield plant^{-1} were obtained from high level of nitrogen (60 kg N fed^{-1}). Also, the highest values of above traits were obtained from irrigation with treated wastewater with nano-titanium dioxide and sandy filter + tap water (W_4). It could be concluded that under the conditions of the experiment, application of high levels of nitrogen (N_{60}) under irrigation with treated wastewater with nano-titanium dioxide and sandy filter+ tap water (W_4) is recommended.

Keywords: Treated wastewater; Nano-titanium dioxide; Nitrogen fertilizer; Yield

Introduction

Barley (*Hordeum vulgare* L.) is an important cereal crop not only in Egypt but also all over the world. Among cereals, it ranks fourth concerning area and production after wheat, rice and maize. Barley is a winter cereal crop in Egypt and usually used as food for humans and feed for animals and poultry birds.

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Received: January 27, 2021;
Accepted: February 16, 2021;
Published: February 25, 2021.

Nitrogen is a constituent's plant proteins, chlorophyll, nucleic acids and other substances are considered the most important nutrients. Increasing N-fertilizer levels significantly increased yield and yield components as well as the grain protein content of barley (Orphanos,1992; El-Badry, 1995; Megahed, 2003; Yadav *et al,* 2003; Patel *et al,* 2004; Youssef *et al.*, 2004; Alazmani, 2015; Puniya *et al,* 2015. El-Moselhy and Zahran (2003) indicated that plant height, spike length, number of spikes, number of grains/spike, and grain yield were significantly increased by increasing nitrogen rate. Mousavi *et al* (2012) studied the effect of nitrogen levels on the growth and morphological traits of barley. They found that the nitrogen levels were significant on plant height, ear length, and seed yield. The data showed that 150 kg N ha^{-1} fertilizer treatment produced the maximum of all studied traits, but has no significant differences with 100 kg N ha^{-1}.

The high demand for barley for animal feed and shortage of tap water increases the need for the reuse of treated wastewater as an alternative source for irrigation. Using alternative water resources such as tertiary treated sewage wastewater are considered very important to produce crops as barley due to irrigation water shortage, especially in arid and semiarid regions such as Upper Egypt. The traditional methods of treatment are not efficient enough to completely remove the emerging contaminants (Qu *et al*, 2012). The biological wastewater treatment is widely applied but these are usually slow, limited due to the presence of non-biodegradable contaminant, and sometime causes toxicity to microorganisms due to some toxic contaminants (Zelmanov and Semiat, 2008), besides, to the accumulation of potentially toxic elements in soils and plants (Ahmadifard, 2014). Recently, it is critical to develop and implement advanced wastewater treatment technologies with high efficiency and low capital requirement. Among various advanced treatments, the use of nanotechnology which has been attracting the attention of scientists. Nano-materials are the smallest structures that humans have developed, a having size of a few nanometers (Chaturvedi *et al*, 2012). More precisely, the nano-particles are those that have structure components with one dimension at least less than 100 nm (Amin *et al*, 2014). Several investigations have been published in nano-adsorption materials which aimed to study the removal of pollutants from wastewater (Shamsizadeh *et al*, 2014; Tang *et al*, 2014; Zhang *et al*, 2014a&b; Kyzas and Matis, 2015). Haddad *et al* (2017) studied the effect of irrigation with fresh and wastewater on growth and yield of seven non-local cultivars (S42IL107, BW284, BW281, G400, Scarlett, Bowman and BW290) of Barley (*Hordeum vulgare* L.). They showed that barley cultivars irrigated with both fresh and wastewater had, in general, the same growth vigor and growth nature. The cultivars irrigated with wastewater gave nearly twice the yield of that irrigated with freshwater. This undertaken aimed to investigate the effect of different nitrogen fertilizer levels and types of irrigation water (Tap water and treated wastewater) on yield and its attributes of barley.

Materials and Methods

A pot experiment was carried out at the Experimental Farm, Faculty of Agriculture, South Valley University, Qena, Egypt during the 2015-2016 and 2016-2017 seasons to study the effect of nitrogen fertilizer levels and types of irrigation water on barley cv. Giza 2000 yield and its attributes traits. The seeds of the above mentioned variety were used in the pot experiments. The seeds were sowing on the 17th of November in the 2015/2016 and 2016/2017 seasons. Thirty seeds were initially planted in plastic pots (25 cm diameter and 75 cm height) filled with 13 kg dried soil (1:1 ratio clay and sand). After 21 days from sowing, the plants both seasons were thinned to sixteen plants per pot. The mechanical analysis of the used soil and heavy metals in types of water are presented in Tables 1 and 2.

Table 1. Some physical, macro, and heavy elements properties in the soil before planting at the two seasons.

Properties	2015/2016	2016/2017
Clay%	13.88	14.85
Silt%	17.00	18.00
Sand%	69.12	67.15
Soil texture	Sandy loam	Sandy loam
N (PPm)	33.6	35.3
P (PPm)	0.22	4.6
K (PPm)	219.4	361.3
Pb (PPm)	1.40	1.26
Ni(PPm)	0.34	0.36
Cd (PPm)	0.018	0.016
Cr (PPm)	2.88	3.02

Table 2. Heavy metals present in different types of water.

Types of water	Heavy metals			
	Pb (PPm)	Ni (PPm)	Cd (PPm)	Cr (PPm)
W_1	0.0	0.029	0.0	0.457
W_2	0.0	0.103	0.0	0.552
W_3	0.0	0.139	0.0	0.623
W_4	0.0	0.132	0.0	0.525

A randomized complete block design (RCBD) using a split-plot arrangement with four replications was used. The main plot was four different levels of nitrogen fertilizer (0.00, 30.00, 45.00, and 60.00 kg fed.$^{-1}$) from urea source and sub-plot were four different types of irrigation water (W_1; Tap water only, W_2; manipulated wastewater with sandy filter, W_3; manipulated wastewater with nano-titanium dioxide + sandy filter and W_4; a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water 1:1). Other agricultural practices were applied according to the recommendation at the two seasons.

At harvest time**,** ten plants were taken from each pot to measure the following traits: plant height (cm), number of tillers plant^{-1}, spike length (cm), and grain yield/plant (g).

The obtained data were subjected to analysis of variance according to Gomez and Gomez (1984) by MSTAT-C Computer program. Comparison between treatment means was done by least significant difference (LSD) procedures at 5% level of probability.

Results and Discussion

Plant height:

Data in Table 3 show that plant height varied significantly by used nitrogen levels in the two seasons. Application of 60 kg N/feddan surpassed the 0.00 kg N/feddan in this respect and gave the highest mean values of plant height in both seasons. These results can be ascribed by the role of nitrogen in cell deviation and elongation as well as the photosynthesis process, which is reflected in growth. The results are in accordance with those of El-Moselhy and Zahran (2003), El-Metwally *et al* (2010), Ali (2011), Mousavi *et al* (2012), Fazal *et al* (2013), Singh *et al* (2013a), Alazmani (2015), Aleminew and Legas (2015), Shendy *et al* (2016) & Reddy and Singh (2018). Also, the data in the same Table illustrate a significant effect of irrigation water types on plant height in the two growing seasons. The highest average values for this trait were obtained by treated wastewater + nano-titanium dioxide and sandy filter + tap water in both seasons. It might be due to the high nitrogen content in the treated wastewater. Similar findings were also reported by Al Ajmi *et al* (2009), Haddad *et al* (2017), Rawashdeh (2017), Alawsy *et al* (2018) and Samarah *et al* (2020). Result indicates that there was significant effect of the interaction between nitrogen levels and irrigation types of water (N × W) on plant height in both seasons. Application of 60 kg N fed.$^{-1}$ markedly improved plant height when wastewater + nano-titanium dioxide and sandy filter + tap water were added height in both seasons. However, the lowest mean values of this character were obtained from $N_0 \times W_1$ at two seasons. Similar results were obtained by Mousavi *et al* (2012).

Table 3. Effect of nitrogen levels and irrigation water types on plant height (cm) in 2015/2016 and 2016/2017 seasons.

Seasons / Nitrogen levels (kg/fad.) (N) / Water types (w)	2015/2016 N_0	N_{30}	N_{45}	N_{60}	Mean	2016/2017 N_0	N_{30}	N_{45}	N_{60}	Mean
W_1	65.00	66.46	78.05	76.13	71.41	51.10	58.28	57.10	57.75	56.06
W_2	74.06	70.31	79.87	83.33	76.89	53.40	57.93	61.33	65.73	59.60
W_3	70.30	74.77	73.45	73.35	72.97	57.13	56.33	57.50	56.30	56.82
W_4	72.05	72.35	82.37	87.80	78.64	53.98	59.33	62.20	64.38	59.97
Mean	70.35	70.97	78.44	80.15	74.98	53.90	57.97	59.53	61.04	58.11
$LSD_{0.05}$	N		W	N × W		N		W	N × W	
	6.24		3.49	7.01		3.20		2.55	5.11	

W_1, W_2, W_3 and W_4; Tap water, manipulated wastewater with sandy filter, manipulated wastewater with nano-titanium dioxide + sandy filter and a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water, respectively.

Number of tillers/plant:

Nitrogen fertilizer had significant influence on number of tillers/plant (Table 4). The highest number of tillers/plant was achieved fromN_{60} treatment. The lowest of them related to control (N0). Similar findings were also reported by Aghdam and Samadiyan (2014), Reddy and Singh (2018) and Wali *et al* (2018). While, Tigre *et al* (2014) stated that the effect of N on several of total tillers was not significant.Irrigation water types had a significant influence on the number of tillers plant^{-1} (Table 4). The highest number of tillers plant^{-1} was obtained by irrigation wastewater with nano-titanium dioxide and sandy filter + tap

Table 4. Effect of nitrogen levels and irrigation water types on the number of tillers plant-1 in 2015/2016 and 2016/2017.

Seasons / Nitrogen levels (kg N/fad.) / Water types (w)	2015/2016 N_0	N_{30}	N_{45}	N_{60}	Mean	2016/2017 N_0	N_{30}	N_{45}	N_{60}	Mean
W_1	1.725	1.800	2.050	1.900	1.869	1.404	2.083	1.719	2.301	1.877
W_2	1.625	1.800	2.175	2.175	1.944	1.679	2.313	2.208	2.969	2.292
W_3	1.900	1.863	2.025	1.975	1.941	2.010	2.074	1.888	3.063	2.259
W_4	2.067	2.075	1.625	2.150	1.979	2.130	1.919	2.297	3.141	2.372
Mean	1.829	1.885	1.969	2.050	1.933	1.806	2.097	2.028	2.869	2.200
$LSD_{0.05}$	N 0.094		W 0.053		N × W 0.103	N 0.406		W 0.307		N × W 0.610

W_1, W_2, W_3 and W_4; Tap water, manipulated wastewater with sandy filter, manipulated wastewater with nano-titanium dioxide + sandy filter and a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water, respectively.

water. Nevertheless, the lowest mean values of tillers number plant-1 was obtained from irrigated with tap water in both seasons.

Also, the interaction had a significant influence on number of tillers plant-1 (Table 4). Treatment N_{60} x W_4 (60 kg N/feddan and wastewater + nano-titanium dioxide + sandy filter) gave the highest mean values of tillers number plant-1 in both seasons.

Spike length:

Spike length varied significantly by studied nitrogen levels in the two growing seasons (Table 5). Application of 60 kg N/feddan surpassed the three other levels in this respect and gained the longest mean values of spike length. These results can be ascribed by the role of nitrogen in cell deviation and elongation as well as the photosynthesis process which is reflected in growth. The previous finding is in agreement with those emphasized by Gauer *et al* (1992), Patke *et al* (2003),Turk *et al* (2003), AbdAlla (2004), Khedr and Nemeat-Alla (2006), El-sheref *et al* (2007), Blackshaw and Brandt (2008), Nassar (2008), El-Metwally *et al* (2010), Shalaby *et al* (2006), Ali (2010), Ali (2011), Mousavi *et al* (2012), Aghdam and Samadiyan (2014), Reddy and Singh (2018) and Wali *et al* (2018).

N/feddan markedly improved plant height when wastewater + nano-titanium dioxide and sandy filter + tap water were added height in both seasons.

Data in Table 5 illustrated the significant effect of water types on spike length in both growing seasons. The highest mean values of the mentioned trait were recorded by irrigation with wastewater +nano- titanium dioxide and sandy filter + tap water. On the contrary, tap water recorded the lowest values for this trait. Similar results were obtained by Hadad *et al* (2017).

Moreover, data-focused that the interaction between nitrogen levels and irrigation water had a significant influence on spike length in the two growing seasons. Irrigation with wastewater + nano-titanium dioxide and

Table 5. Effect of nitrogen levels and irrigation water types on the spike length (cm) in 2015/2016 and 2016/2017.

Seasons	2015/2016					2016/2017				
Nitrogen levels (kg N/fad.) / Water types (w)	N_0	N_{30}	N_{45}	N_{60}	Mean	N_0	N_{30}	N_{45}	N_{60}	Mean
W_1	16.35	16.64	16.85	18.08	16.98	14.56	15.34	15.09	15.28	15.07
W_2	17.1	16.99	18.55	18.31	17.74	14.50	15.05	16.50	15.13	15.30
W_3	16.71	16.39	18.52	17.38	17.25	14.50	15.30	15.01	16.03	15.21
W_4	18.09	18.5	18.81	18.94	18.59	16.39	15.93	15.86	16.75	16.23
Mean	17.06	17.13	18.18	18.18	17.64	14.99	15.41	15.62	15.80	15.45
$LSD_{0.05}$	N		W	N × W		N		W	N × W	
	0.76		0.58	1.16		0.52		0.40	0.81	

W_1, W_2, W_3 and W_4; Tap water, manipulated wastewater with sandy filter, manipulated wastewater with nano-titanium dioxide + sandy filter and a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water, respectively.

sandy filter + tap water and 60 kg N/feddan gained the significant maximum values of spike length. The lowest spike length was obtained from $N_0 \times W_1$ and $N_0 \times W_2$ in the first and second seasons, respectively. Similar results were obtained by Mousavi *et al* (2012).

Spike weight:

Data in Table 6 shows the nitrogen fertilization treatments had a significant effect on spike weight in both seasons. Application of high level of nitrogen (60 kg fed^{-1}) gave the highest mean values of spike weight in both seasons. These results are in accordance with those of Turk *et al* (2003), AbdAlla (2004), Khedr and Nemeat-Alla (2006), El-sheref *et al* (2007), Blackshaw and Brandt (2008), Nassar (2008), El-Metwally *et al* (2010), Ali (2011), Reddy and Singh (2018) and Wali *et al* (2018).

As for irrigation water types, these treatments affected significantly the spike weight in both seasons. Results in Table 6 indicate that the W_4 (treated wastewater with nano-titanium dioxide and sandy filter + tap water) surpassed all other irrigation water types in both seasons. Similar findings were also reported by Hadad *et al* (2017) and Samarah *et al* (2020)

Regarding the effect of the interaction between nitrogen fertilization treatments and irrigation water type (N × W), this interaction was significant on spike weight in both seasons. Application of 0.0 kg N/feddan markedly decreased spike weight when irrigated with tap water in both seasons. But, the highest spike weight was recorded with 60 kg N fed.$^{-1}$ and irrigated by treated wastewater with nano-titanium dioxide and sandy filter + tap water in both seasons.

Number of grains spike^{-1}:

Nitrogen levels appreciably influenced the average number of grains spike^{-1} in both growing seasons as illustrated in Table 7. In this respect, with each increase in nitrogen level, there was a progressive increase in the number of grains spike^{-1}. Application of nitrogen at 60 kg N fed.$^{-1}$ recorded the highest values of the number of grains. On the other

Table 6. Effect of nitrogen levels and irrigation water types on spike weight (g) in 2015/2016 and 2016/2017 seasons.

Seasons	2015/2016					2016/2017				
Nitrogen levels (kg N/fad.) / Water types (w)	N_0	N_{30}	N_{45}	N_{60}	Mean	N_0	N_{30}	N_{45}	N_{60}	Mean
W_1	0.643	0.684	1.443	1.445	1.054	0.706	0.906	0.814	0.738	0.791
W_2	1.230	0.768	1.475	1.575	1.262	0.835	0.973	1.031	1.058	0.974
W_3	0.903	1.609	1.212	1.218	1.236	0.929	0.891	0.859	1.097	0.944
W_4	1.502	1.432	1.584	1.649	1.542	0.963	0.94	1.053	1.183	1.035
Mean	1.070	1.123	1.429	1.472	1.273	0.858	0.928	0.939	1.019	0.936
$LSD_{0.05}$	N	W	N × W			N	W	N × W		
	0.362	0.156	0.319			0.063	0.091	0.170		

W_1, W_2, W_3 and W_4; Tap water, manipulated wastewater with sandy filter, manipulated wastewater with nano-titanium dioxide + sandy filter and a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water, respectively.

Table 7. Effect of nitrogen levels and irrigation water types on number of grains/spike in 2015/2016 and 2016/2017 seasons.

Seasons	2015/2016					2016/2017				
Nitrogen levels (kg N/fad.) / Water types (w)	N_0	N_{30}	N_{45}	N_{60}	Mean	N_0	N_{30}	N_{45}	N_{60}	Mean
W_1	9.17	10.75	23.13	24.63	16.92	8.50	15.00	10.65	11.75	11.48
W_2	16.57	27.20	19.05	17.75	20.14	12.25	15.13	11.88	16.83	14.02
W_3	20.75	12.25	23.63	21.88	19.63	11.05	12.63	14.75	14.17	13.15
W_4	22.40	24.63	20.13	24.83	23.00	15.63	11.68	15.48	17.63	15.11
Mean	17.22	18.71	21.49	22.27	19.92	11.86	13.61	13.19	15.10	13.44
$LSD_{0.05}$	N	W	N × W			N	W	N × W		
	1.39	1.03	2.06			1.10	1.03	2.04		

W_1, W_2, W_3 and W_4; Tap water, manipulated wastewater with sandy filter, manipulated wastewater with nano-titanium dioxide + sandy filter and a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water, respectively.

side, the lowest number of grains spike^{-1} was recorded with N_0. Nitrogen fertilizer encourages the absorption of nitrogen in the plant and this might be the cause of the obtained increase in number of grains/spike. The same conclusion was mentioned by Turk *et al* (2003), AbdAlla (2004), Khedr and NemeatAlla (2006), El-Sheref *et al* (2007), Blackshaw and Brandt (2008), Nassar (2008), El-Metwally *et al* (2010), Ali (2011), Reddy and Singh (2018) and Wali *et al* (2018). As shown in Table 7, all treated wastewater significantly improved the number of grains spike^{-1} in the first and second seasons. The highest number of grains/spike were obtained from treated wastewater with nano-titanium dioxide and sandy filter+ tap water, followed by manipulated wastewater with sandy filter and manipulated wastewater with nano-titanium dioxide in the first and second seasons, respectively. In contrast, the lowest statistical values of this trait received by tap water treatment. Similar results were obtained by several workers Hadad *et al* (2017) and Samarah *et al* (2020). Results show that there was a significant effect of the interaction between nitrogen levels and irrigation types of water on the number of grains spike^{-1} in both seasons. Application of 0.0 kg N fed.$^{-1}$ markedly decreased number of grains spike^{-1} irrigated when with tap water in both seasons. But, the highest number of grains spike^{-1} was recorded when addition of 60 kg N fed^{-1} and irrigated with treated wastewater with nano-titanium dioxide and sandy filter+ tap water in both seasons.

Biological yield plant^{-1}:

The presented data in Table 8 revealed that the studied nitrogen levels had a significant effect on biological yield plant^{-1} of barely plants in both seasons. Thus, the highest mean values of biological yield plant^{-1} (3.691 and 3.181 g in the two respective seasons) were obtained from barely plants, which were fertilized by 60 kg N fed.$^{-1}$ in both seasons. The high level of nitrogen (60 kg N fed.$^{-1}$) outyielded the control treatments (N_0; 0.0 Kg N fed.$^{-1}$) by 17.9 and 9.9% in the first and second seasons, respectively. The significant response of biological yield/ plant could attribute to their essential roles in plant growth. Nitrogen is a part of a large number of necessary organic compounds, including amino acid, proteins, coenzymes, nucleic acid and Chlorophyll. The results are in accordance with those of Turk *et al* (2003), AbdAlla (2004), Khedr and NemeatAlla (2006), El-sheref *et al* (2007), Blackshaw and Brandt (2008), Nassar (2008), El-Metwally *et al* (2010), Mousavi *et al* (2012), Helmy *et al* (2013), Reddy and Singh (2018) and Wali *et al* (2018).

Results point out a significant effect of irrigation water types on biological yield plant^{-1} in both seasons. The application of W_4 (Irrigation with wastewater + nano-titanium dioxide and sandy filter + tap water) gave the highest values of biological yield plant^{-1} (3.683 and 3.261 in the first and second seasons, respectively). The results are in accordance with those of Haddad *et al* (2017).

Moreover, the interaction between nitrogen fertilization treatment and irrigation water types (N × W) had a significant effect on biological yield plant^{-1} in the two growing seasons. The highest mean values of biological yield plant^{-1} (4.037 and 3.750 in the first and second seasons, respectively) were obtained from $N_{60} \times W_4$. The significant response can be attributing to a different trend of response, which was observed in plants application water type under nitrogen treatments.

Grain yield plant^{-1}:

Data in Table 9 indicate significant increases of grain yield plant^{-1} with increasing nitrogen levels from 0.0 to 60 kg N fed^{-1} at both seasons. Application of 60 kg N fed^{-1} led to the significantly increased maximum values of grain yield plant^{-1} (0.934 and 0.618 g in the first and second seasons, respectively). On the other hand, the lowest (0.745 and 0.490 g) of aforementioned trait was obtained by addition of 0.0 kg N fed^{-1} in both seasons.

Table 8. Effect of nitrogen levels and irrigation water types on biological yield plant^{-1} (g) in 2015/2016 and 2016/2017.

Seasons	2015/2016					2016/2017				
Nitrogen levels (kg N/fad.) / Water types (w)	N_0	N_{30}	N_{45}	N_{60}	Mean	N_0	N_{30}	N_{45}	N_{60}	Mean
W_1	2.492	2.571	3.472	3.742	3.069	2.178	2.828	2.391	2.660	2.514
W_2	2.486	3.209	3.705	3.735	3.284	3.429	2.982	3.233	3.139	3.196
W_3	3.676	2.719	3.263	3.250	3.227	3.010	2.579	2.850	3.175	2.904
W_4	3.471	3.644	3.578	4.037	3.683	2.850	3.123	3.322	3.750	3.261
Mean	3.031	3.036	3.505	3.691	3.316	2.867	2.878	2.949	3.181	2.969
$LSD_{0.05}$	N	W	N × W			N	W	N × W		
	0.477	0.299	0.600			0.202	0.263	0.527		

W_1, W_2, W_3 and W_4; Tap water, manipulated wastewater with sandy filter, manipulated wastewater with nano-titanium dioxide + sandy filter and a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water, respectively.

Table 9. Effect of nitrogen levels and irrigation water types on grain yield/plant in 2015/2016 and 2016/2017.

Seasons	2015/2016					2016/2017				
Nitrogen levels (kg N/fad.) / Water types (w)	N_0	N_{30}	N_{45}	N_{60}	Mean	N_0	N_{30}	N_{45}	N_{60}	Mean
W_1	0.300	0.409	0.997	0.912	0.655	0.357	0.623	0.532	0.454	0.492
W_2	0.780	0.664	0.917	1.100	0.865	0.549	0.526	0.669	0.685	0.607
W_3	0.767	1.115	0.739	0.729	0.838	0.51	0.53	0.568	0.609	0.554
W_4	0.994	1.025	1.060	1.146	1.056	0.544	0.631	0.683	0.722	0.645
Mean	0.710	0.803	0.928	0.972	0.853	0.490	0.578	0.613	0.618	0.575
$LSD_{0.05}$	N	W	N × W			N	W	N × W		
	0.118	0.111	0.230			0.073	0.065	0.143		

W_1, W_2, W_3 and W_4; Tap water, manipulated wastewater with sandy filter, manipulated wastewater with nano-titanium dioxide + sandy filter and a mixture of treated wastewater with nano-titanium dioxide and sandy filter + tap water, respectively.

This is to be logic since the same fertilizer level increased number of tillers plant^{-1} and number of grains spike^{-1} traits as mentioned before as well as increased spike weight and consequently increased grain yield plant^{-1}. This could be attributed to its simulative effect of the vegetative growth, which increased the photosynthetic rate, number of spikes plant^{-1}, number of spikletes spike^{-1}, spike length and grains number spike^{-1} may account for the superiority of grain yield. Similar results were reported by Turk *et al* (2003), AbdAlla (2004), Khedr and Nemeat-Alla (2006), El-sheref *et al* (2007), Blackshaw and Brandt (2008), Nassar (2008), El-Metwally *et al* (2010), Ali (2011), Mousavi *et al* (2012), Reddy and Singh (2018) and Wali *et al* (2018). Results show that the highest values of grain yield plant^{-1} were obtained from treated wastewater with nano-titanium dioxide and sandy filter+ tap water (W_4) in both seasons. Whereas, the lowest values of this trait was observed from irrigated with tap water (W_1) in both seasons. Application of W_4 outyielded the W_1 treatment by 38.0 and 23.7% in the first and second seasons, respectively. This is to be logic since the water type increased number of tillers/plant and number of grains/spike traits as mentioned before as well as increased spike weight and consequently increased grain yield/plant. Similar findings were also reported by Eid and Shereif (1996), Hadad *et al* (2017) and Samarah *et al* (2020)

There was a significant effect of the interaction between nitrogen levels and irrigation types of water treatments on grain yield plant^{-1} in both seasons. The highest grain yield plant^{-1} (1.146 and 0.772 g) was recorded under 60 kg N/fed and nano-titanium dioxide and sandy filter + tap water in both seasons. However, the lowest grain yield plant^{-1} (0.300 and 0.357 g) was registered from $N_0 \times W_1$in the first and second seasons.

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