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INTERACTIVE EFFECTS BETWEEN IRRIGATION AND NITROGEN TREATMENTS ON YIELD, NITROGEN ACQUISITION AND NITROGEN USE AND AGRONOMIC EFFICIENCIES OF WHEAT PLANT

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ABSTRACT

Field experiments were conducted to investigate the interactive effects between different irrigation treatments and N application rates on grain and straw yields of wheat plants grown on a clay soil and to describe the relationships between irrigation treatments and yield of wheat plants at different N treatments. The factors were nitrogen fertilizer(N): 0(N_0), 75(N_1), 150(N_2), and 225(N_3) kg.ha^{-1} as urea and four treatments of irrigation(I): fully-irrigation with canal water(I_1), 2 times well water + canal water (I_2), 4 times well water + canal water(I_3), and 6 times well water + canal water(I_4). The obtained results indicated that grain and straw yields were significantly increased with increasing application rate of N fertilizer at all treatments of irrigation. On the other hand, grain and straw yields of wheat plants were decreased significantly with increasing number of well water irrigation times. The maximum nitrogen use efficiency (NUE) for grain yield (63.73 kg kg^{-1} N) was found with a 75 kg N ha^{-1} and I_1(fully-irrigation with canal water) . In contrast, the minimum NUE for grain yield (19.56 kg kg^{-1} N) was found with a 225kg Nha^{-1} and I_4 (6 times well water,4500 m^3 ha^{-1}+ canal water, 1500 m^3 ha^{-1})for first season. Similarly, irrigation with well water decreased the agronomic efficiency (AE) for grain yield noticeably at all N application rates. The reduction in AE for grain yield of wheat was much higher at I_4 treatment than of that at I_2 treatment. The mean agronomic efficiency (AE) for grain yield for the second season confirmed the results of first season and was very close to each other. Future research works should be made by further developing more efficient wheat varieties that could use N more efficiently at lower rates (<225 kg N ha^{-1}). It can be concluded that the limited amount of available fresh water should be applied during the initial growth stage and supplemented with well water at later growth stages of wheat plants.

Keywords: Agronomic Efficiency, N Acquisition, N-Use Efficiency, Well water, Wheat Yield

INTRODUCTION

Today, the competition for scarce water resources is intense throughout the world. In such water-limited conditions, wheat productivity is highly dependent on irrigation water availability and quality decline continuously as a result of climate change and increasing consumption. Irrigation water

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Irrigation water is becoming an increasingly limited resource in many areas of Egypt and consequently, an appropriate choice of irrigation scheduling in order to maximize water use efficiency and profit is needed. Moreover, in many situations, wheat is grown mainly in river basins, which are environments sensitive to underground water nitrate pollution risk. An appropriate application of irrigation water (I) and nitrogen (N) fertilizer has the vital purpose of increasing water and nitrogen productivity and reducing environmental pollution risk (English and Raja, 1996). To prevent widespread crop failure, the concept of protective irrigation implying a limited water supply to agricultural lands has been introduced. Currently, communities in most areas of Egypt are faced with water shortage, low water-use efficiency (WUE) and N use efficiency (NUE), and high NO_3—N contamination in groundwater which often exceeds drinking-water standards (Zhang *et al.* 1995, 1996; Ma *et al.* 2005; Yang and Su 2008). It is predicted that these problems will be worse in arid regions in the future, and farmers will have to rely more on underground water and N fertilizer for crop production in order to feed the increasing population (Zhang *et al.* 1996). Crop production systems that optimize yield, reduce N loss and improve N uptake and WUE are desirable.

Nitrogen fertilizer and irrigation water are two major factors influencing wheat yield, N uptake and N loss, which can be controlled by the grower (Ottman and Pope 2000; Yin *et al.* 2007). Nitrogen fertilization also increases crop yield when the soil N supply is low (Fredrick and Camberato 1995a and b; Sexton *et al.*, 1996). Nitrogen application rate was the main factor causing N loss; no NO_3−N leaching was found when the N application was below 150 kgha^{-1},but NO_3−N leaching increased at rates of 225–300 kg N ha^{-1} (Fan *et al.* 1998). Grain yield of wheat, harvest index and NUE reached their highest at an application rate of 225 kg N ha^{-1}. The economic yield is maximum at an application rate of 150–225 kg N ha^{-1} (Li *et al.*, 2001). The partial fertilizer productivity (PFP-grain yield per unit applied N) of applied N fertilizer decreased significantly when N fertilizer input exceeded 200 kg N ha^{-1} for wheat production (Fang, *et al.*, 2006).In general, increased soil water content enhances crop yield response to N fertilization, especially when high N rates are applied (Norwood 2000). In addition, N uptake is strongly influenced by water supply. High NO_3^- leaching occurs with high rainwater and irrigation water supply (Fang, *et al.*, 2006). In a sub-Saharan environment, Pandey *et al.* (2001) reported a linear yield response to irrigation at all N levels.

Generally, the greater the N supply, the more yield was reduced by deficit irrigation. O'Neill *et al.*(2004) reported a greater yield response with N application under adequate soil water conditions, and a lower one under deficit water conditions. They also reported an average yield increase of 23% for adequate versus deficit water supply, and around 100% for adequate versus deficit N levels in the Great Plains of the United States. Appropriate application of irrigation water and N fertilizer has dual vital purposes of increasing water and N productivity and reducing environmental pollution risk (Katterer *et al.*, 1993; Su *et al.*, 2007).

Many studies have been carried out to investigate the effects of N application rates on grain yield and overall N balance in the soil (Liu *et al.*

2001, 2003; Ju *et al.* 2003,2004). Literature on the effects of water and nitrogen on yield and related parameters such as nitrogen use efficiency (NUE), water use efficiency (WUE) and irrigation water use efficiency (IRRWUE) are reported by Dag˘delen *et al.* (2006), Oktem *et al.*(2003), Evett *et al.* (2000, 2001), Howell *et al.* (1998) and Howell (2001). Such studies can provide insight into the knowledge on how deficit irrigation and N rates can be manipulated for spring wheat grown on recently reclaimed sandy farmland. This can maximize grain yield, improve N uptake and minimize N loss in sandy soil. The field experiment was designed to investigate the interactive effects between different irrigation treatments and N application rates on grain and above-ground biomass yields in a clay soil and to describe the relationships between irrigation treatment and yield of wheat plants at different N treatments.

MATERIALS AND METHODS

Climate and soil characteristics:

Two field experiments were conducted at the experimental farm, Soil Salinity and Alkalinity Laboratory, Ministry of Agriculture and Land Reclamation (MALR) at Abis-Alexandria, during the growing seasons: November-April 2008/2009 and 2009/2010. The geographical position is at latitude 31° 2" N, and longitude 29° 6" E with an elevation of about 2.50 m below sea level. The mean annual rainfall was 200 mm and the relative humidity during daytime is about 67.30%. The mean temperature, during November and October, ranged between 23°C and 15 °C.

The soil chemical and physical properties were determined as follows: The pH was measured in 1:2.5 soil water suspension and the electrical conductivity(EC) was measured in saturated soil-paste extract (Richard, 1954);organic matter by dichromate oxidation method (Nelson and Sommers, 1982); cation exchange capacity (CEC) by IM neutral NaOAc method (Rhoades, 1982); total calcium carbonate by a calcimeter method (Nelson, 1982);available P by 0.5 M $NaHCO_3$ test (Olsen and Sommers, 1982);available nitrogen by 2M KCl method (Bremner and Mulvaney, 1982);available potassium by 1N neutral ammonium acetate method (Knudsen and Peterson,1982); particle size distribution by the hydrometer method (Day, 1965); and the bulk density by clod method (Tan,1996). The soil chemical and physical properties are presented in Table (1). It is clear that the soil had a clay texture with 431.67 gkg^{-1} clay, 322.33 gkg^{-1} silt and 246 gkg^{-1} sand.

Experimental design:

The experimental set-up was randomized complete block design with four replicates and thirteen treatments for N fertilizer rates and irrigation treatments. Plot size was $9m^2$. The factors were nitrogen fertilizer at rates of $0(N_0)$, $75(N_1)$, $150(N_2)$, and $225(N_3)$ $kg.ha^{-1}$ as urea and four treatments of irrigation: fully-irrigation with 6000 m^3ha^{-1} canal water(I_1), 2 times well water(1500 m^3ha^{-1}) + 4500 m^3ha^{-1} canal water (I_2), 4 times well water(3000 m^3ha^{-1}) + 3000 m^3ha^{-1} canal water(I_3), and 6 times well water (4500 m^3ha^{-1} + 1500 m^3ha^{-1} canal water(I_4) .The mineral nitrogen fertilizer was applied in two equal doses: before sowing and 21 days after sowing wheat seeds(*Triticum aestivum* c.v. Sakha 94). The phosphorus and potassium fertilizers were applied to the soil before sowing. The applications of N fertilizer rates and irrigation treatments yielded a total of thirteen treatments:

N_0I_1: 0 kg $N.ha^{-1}$ + fully-irrigated with canal water (6000 m^3ha^{-1})
N_1I_1: 75 kg $N.ha^{-1}$ + fully-irrigated with canal water
N_2I_1: 150kg $N.ha^{-1}$ + fully-irrigated with canal water
N_3I_1: 225kg $N.ha^{-1}$ + fully-irrigated with canal water
N_1I_2: 75 kg $N.ha^{-1}$ + 2 times well water (1500 m^3ha^{-1}) + canal water (4500 m^3ha^{-1})
N_2I_2: 150 kg $N.ha^{-1}$ + 2 times well water + canal water
N_3I_2: 225 kg $N.ha^{-1}$ + 2 times well water + canal water
N_1I_3: 75kg $N.ha^{-1}$ + 4 times well water (3000 m^3ha^{-1}) + canal water (3000 m^3ha^{-1})
N_2I_3: 150kg $N.ha^{-1}$ + 4 times well water+ canal water
N_3I_3: 225 kg $N.ha^{-1}$ + 4 times well water+ canal water
N_1I_4: 75kg $N.ha^{-1}$ + 6 times well water (4500 m^3ha^{-1}) + canal water (1500 m^3ha^{-1})
N_2I_4: 150 kg $N.ha^{-1}$ + 6 times well water+ canal water
N_3I_4: 225kg $N.ha^{-1}$ + 6 times well water+ canal water

The sources of irrigation water were canal and well (Table 2).

Plant sampling and analysis:

The plants were harvested at April 25, 2009 and 2010. The grains were separated from the whole plant. The plant samples were first washed with tap water followed by distilled water and oven dried at 75 ^{0}C for 48 hrs. and then weighed and ground in a stainless steel mill. Sub-samples of ground plant material were dry-ashed in a muffle furnace at 450 ^{0}C for 6 hrs. and the ash was dissolved in diluted nitric acid (1:1), then diluted to a constant volume with distilled water and analyzed for total phosphorus and total potassium. Other plant sub-samples were wet-digested by sulfuric acid and hydrogen peroxide, diluted to a constant volume with distilled water and analyzed for total nitrogen (Jones, 2001).

Dry matter production of straw and grain yield is expressed on dry weight basis. Plant nitrogen uptake was calculated in first and second seasons from multiplying concentrations in grain and straw by dry matter of both.

Water sampling and analysis:

Representative water samples (500 ml) were collected in polyethylene bottles, which properly washed/rinsed with the same water that is being sampled. Water samples were taken from two sources, the first source represents canal water, and the second represents well water. After proper labeling (e.g. source of water, date of collection, and type of analysis required), the samples were sent immediately to the laboratory. The water samples were filtered and analyzed for EC, soluble cations and anions (Richards, 1954), but the pH of water samples was measured before filtration of samples (Richards, 1954); Sodium adsorption ratio (SAR) was calculated in order to determine the sodicity or alkalinity hazard of irrigation waters. Water analysis data are presented in Table (2)

Nitrogen use efficiency:

Nitrogen use efficiency (NUE) is defined as a unit of grain produced per unit of nitrogen applied. This would mean that all the nitrogen applied was taken into consideration. The NUE was calculated by dividing the grain yield with the total amount of nitrogen applied for each treatment. The following equation was used to calculate NUE :

$$NUE = TGY/TNA$$

Where NUE is Nitrogen-use efficiency, TGY is total grain yield in kilograms per hectare and TNA is total nitrogen applied in kilograms per hectare.

Agronomic efficiency:

Agronomic efficiency (AE) was calculated using the following equation:

$$AE = GY_i - GY0/N_i$$

Where GY_i and GY_0 are grain yield at N_i inputs and the control (N_0), respectively.

Statistical and mathematical analyses:

The two-way analysis of variance (ANOVA) was carried out to determine the statistical significance of the treatment effects on grain or above-ground biomass yield ,nitrogen use efficiency, agronomic efficiency, and nitrogen acquisition, with the Fisher's least significant difference procedure at a significant level of 0.05 (SAS Institute, 1994). The polynomial quadratic model was used to describe the relationship between units of irrigation with well water and grain and above-ground yields of wheat plants grown on soils treated with different rates of nitrogen fertilizer.

The polynomial quadratic model used is in the form:

$$Y_i = a + bX_i \pm CX^2_i$$

Where Y_i is the expected grain or above-ground biomass yields corresponding to units of irrigation with well water Xi at each N rate, *a* is the intercept, b and C are the linear and quadratic coefficients, respectively.

The maximum yield and maximum applied irrigation unit for all nitrogen treatments were calculated as follows:

$$Y_{max} = a- (b^2/4C)$$

$$I_{max} = - b/2C$$

Where Y_{max} is the maximum grain or above-ground biomass yields corresponding to units of irrigation with well water (I_{max}) at nitrogen rate, *a* is the intercept and b, C are the linear and quadratic coefficients, respectively.

RESULTS

Soil and water characterization:

The experimental soil was classified as a clay soil (*Typic Torrifluvents*) with a relatively medium total carbonate (61.04 gkg^{-1}) and poor in organic matter content (16.00 $g.kg^{-1}$). Implying any crop and soil differences experienced during the experiments may be attributed to the treatment and not to soil heterogeneity. The electrical conductivity of soil is relatively low

(1.87 dSm^{-1}) and below 4 dSm^{-1} and the value of CEC of the soil indicates its ability to supply cationic nutrients for plant growth (Table 1).

Table (1): The main physical and chemical characteristics of the field experimental soil [a]

Characteristics	Unit	Value
Sand	$g\ kg^{-1}$	244.00±5.29
Silt	$g\ kg^{-1}$	324.54± 2.52
Clay	$g\ kg^{-1}$	431.46±4.69
Soil Texture		Clay
D_b	$Kg.m^{-3}$	1350±11.00
EC†	dSm^{-1}	1.87±0.12
pH(range)‡		7.70-8.08
Total $CaCO_3$	$g\ kg^{-1}$	61.04±3.56
O.M†	$g\ kg^{-1}$	16.41±0.86
CEC	$Cmol(+)\ kg^{-1}$	27.84± 3.69
Available-P	$mg\ kg^{-1}$	10.55±0.43
Available-N	$mg\ kg^{-1}$	14.24±0.89
Available-K	$mg\ kg^{-1}$	132.85±6.43

[a] Data are the samples
± standard deviation except for pH
† in soil paste extract
‡ in soil paste

As compared with the USEPA (1993) , for maximum allowed irrigation water criteria, the data presented in Table (2) showed an increase in soluble ions, except for Ca and Mg, and SAR in well water as compared to canal water. The EC of well water was more than 3 dSm^{-1}. The concentrations of chloride, sodium and bicarbonate, and the value of SAR were more than the US EPA allowed irrigation water criteria.

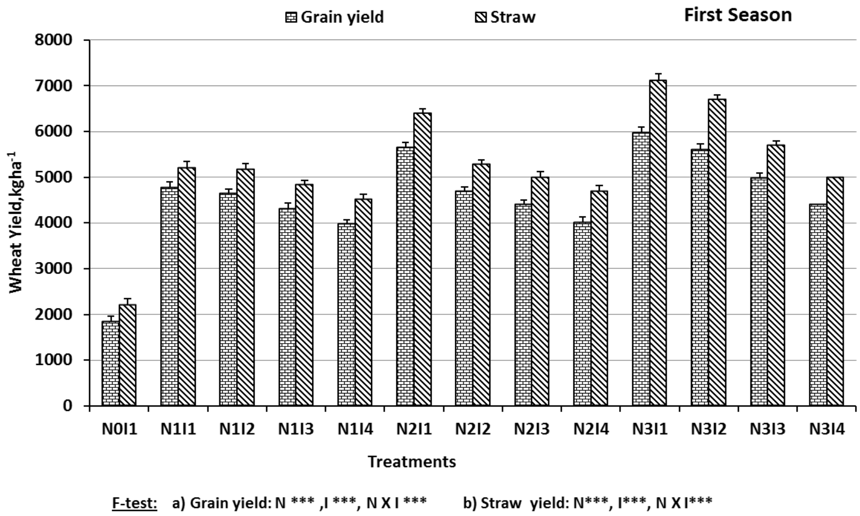
Table (2): The chemical analysis of the irrigation waters used in the study (means ± SD except for pH).[a]

Sources of Irrigation Water	EC dSm^{-1}	pH	Na^{+1}	Ca^{+2}	Mg^{+2}	Cl^{-1}	HCO_3^{-1}	SAR
			meql^{-1}					
Canal	0.62±0.05	7.19	2.78±0.10	1.09±0.050	0.52±0.03	2.30±0.73	4.20±0.20	3.12±0.18
Well	4.39±0.11	8.17	39.00±0.70	1.22±0.090	2.48±0.45	25.00±1.62	7.00±0.87	28.67±2.34
IWC [b]	3.00	6.50-9.00	3.00	20.00	5.00	10.00	1.50	6-12

[a] Means of three samples ± SD.
[b] IWC: Irrigation water criteria, US EPA 1992

Grain and straw yields:

Grain and straw yields were significantly increased *($P< 0.05$)* with increasing application rate of N fertilizer at all treatments of irrigation in the two successive seasons (Fig. 1) .The average high grain yield was 5970 kg ha^{-1} at N_3I_1 (225 kg N. ha^{-1} and fully irrigated with canal water), while the lowest was 1840 kg ha^{-1} at N_0I_1 in first season. The same trend was observed for straw yield and the values were 7120 and 2200 kg ha^{-1} at N_3I_1 and N_0I_1, respectively. Similarly, grain and straw yields of wheat were decreased significantly ($P \leq 0.05$) with increasing number of well water irrigation times (Fig.1).Irrigation with well water, however, decreased the grain yield noticeably ($P \leq 0.05$) from 5970 $kg.ha^{-1}$ at N_3I_1 to 4400 $kg.ha^{-1}$ at N_3I_4(Fig.1) in first season.



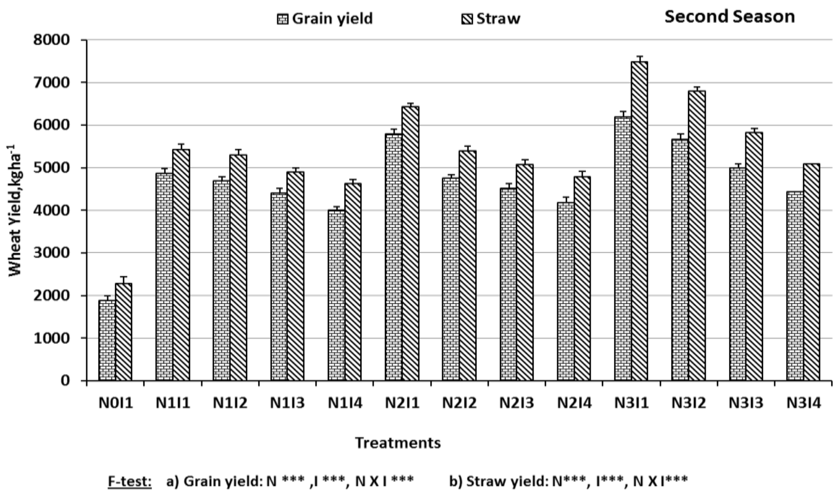


Fig.1: Grain and straw yields of wheat plant grown on soil treated with different treatments of N fertilizer and irrigation in two successive seasons.

The same trend was found at $N_1I_1$and N_1I_4, and N_2I_1 and N_2I_4 (Fig.1).The reduction in grain and straw yields of wheat were much higher at I_4 than at I_2. The reduction percentages were 3%, 10%, and 17% at I_2, I_3, and I_4, respectively (Fig.1). The interaction effects between N application rates and irrigation treatments with well water on grain and straw yields were significant ($P \leq 0.001$) (Fig.1). These results were confirmed with the results of the second seasons.

The polynomial quadratic model was used to describe the relationship between grain and straw yields and irrigation units of well water at all N application rates for the two successive seasons. The method of the least squares was used to calculate the values of B_0, B_1 and B_2 in the polynomial model. Thus 12 polynomial quadratic models were established to express the relationship between grain and straw yields and irrigation units of well water at all N application rates for the two successive seasons. The eight models are shown in Figs. (2 and 3). The calculated grain and straw values were close to the experimental values as shown from the values of standard error of estimates (SE) and determination coefficient (R^2)(Figs. 2 and 3). The maximum yield for grains was significantly decreased ($p< 0.05$) with increasing the number of irrigation times with well water altered with canal water at all N application rate (Table 3).

The values for maximum grain yield were 6655.93, 4015.58 and 4875.60 kg.ha^{-1} at N_3, N_1, and N_2, respectively. These values were corresponding to maximum number of irrigation with well water units of -2.58, 4.40, and -0.34, respectively (Table 3). Similarly, the values for maximum straw yield were 18035.07, 4936.37 and 4232.43 kg.ha^{-1} at N_3, N_1, and N_2, respectively. These values were corresponding to maximum number of irrigation with well water units of -40.10, -0.13, and 3.92, respectively (Table 3). These results were confirmed in the second season.

Table (3): Maximum grain and straw yields and maximum unit of irrigation for grain and straw of wheat plants grown on soil treated with different nitrogen treatments for two seasons.

Treatments	Maximum Yield,kg.ha^{-1}			
	Grain		Straw	
	First season	Second season	First season	Second season
N-75	4875.60	5231.67	4936.37	5421.61
N-150	4015.58	4728.04	4232.43	5079.09
N-225	6655.93	8152.13	18035.07	8036.04
Maximum unit of irrigation				
N-75	-0.34	0.70	-0.13	1.07
N-150	4.40	3.84	3.92	2.95
N-225	-2.58	-2.76	-40.10	-0.98

Nitrogen acquisition:

N accumulation in the grain and straw of wheat in the first and second seasons are shown in figure (4). Nitrogen accumulation in grains or straw was significantly increased with increasing N application rates (N_1-N_3) compared with the control treatment (N_0). Its accumulation in grain or straw at all treatments (N0I1- N3I4) significantly increased in a stepwise fashion and the values were higher at N3I1 followed by N3I2,N3I3,and N3I4 treatments than the values of other treatments in the two seasons (Fig.4). At 150 kg $N.ha^{-1}$ N accumulation was lower than that at 225 kg $N.ha^{-1}$ at the same treatment of irrigation. Irrigation treatments, nitrogen application rates and their interactions significantly ($p< 0.01$) affected N accumulation in grain or straw of wheat plants (Fig.4). These results were confirmed in the second season.

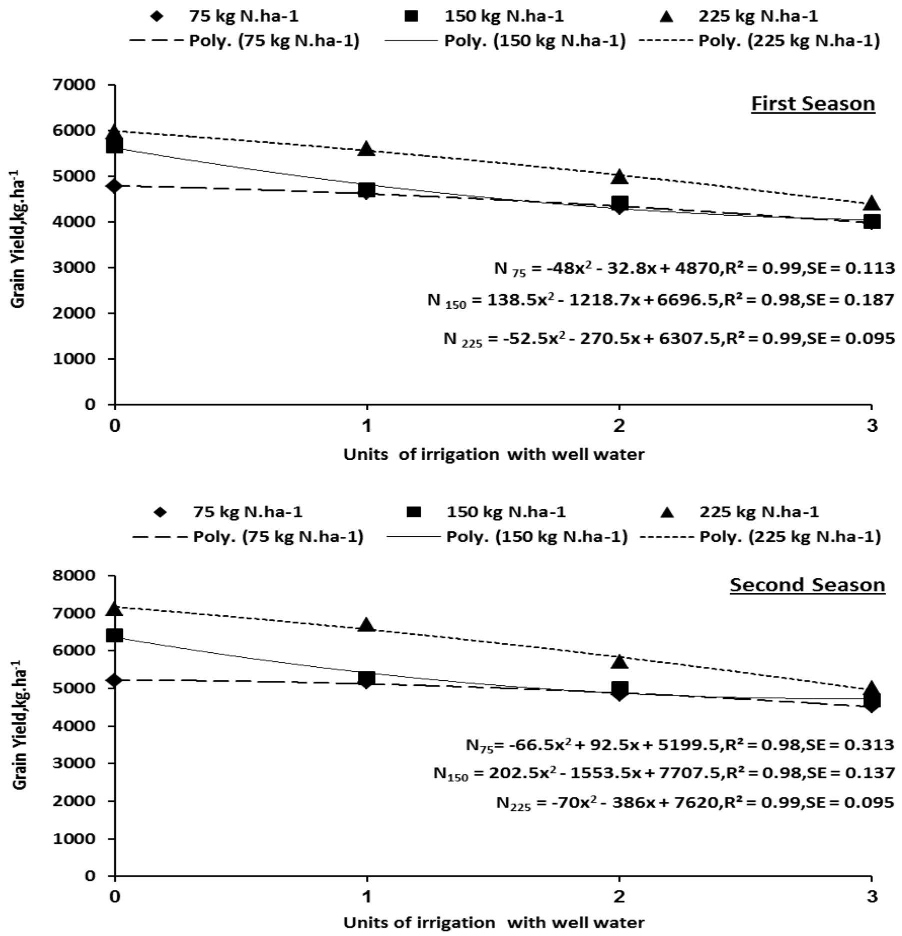


Fig.2: Polynomial quadratic models for grain of wheat plants grown on soil treated with different treatments of N fertilizer and irrigation in two successive seasons. One unit of irrigation = 2 times of irrigation with well water.

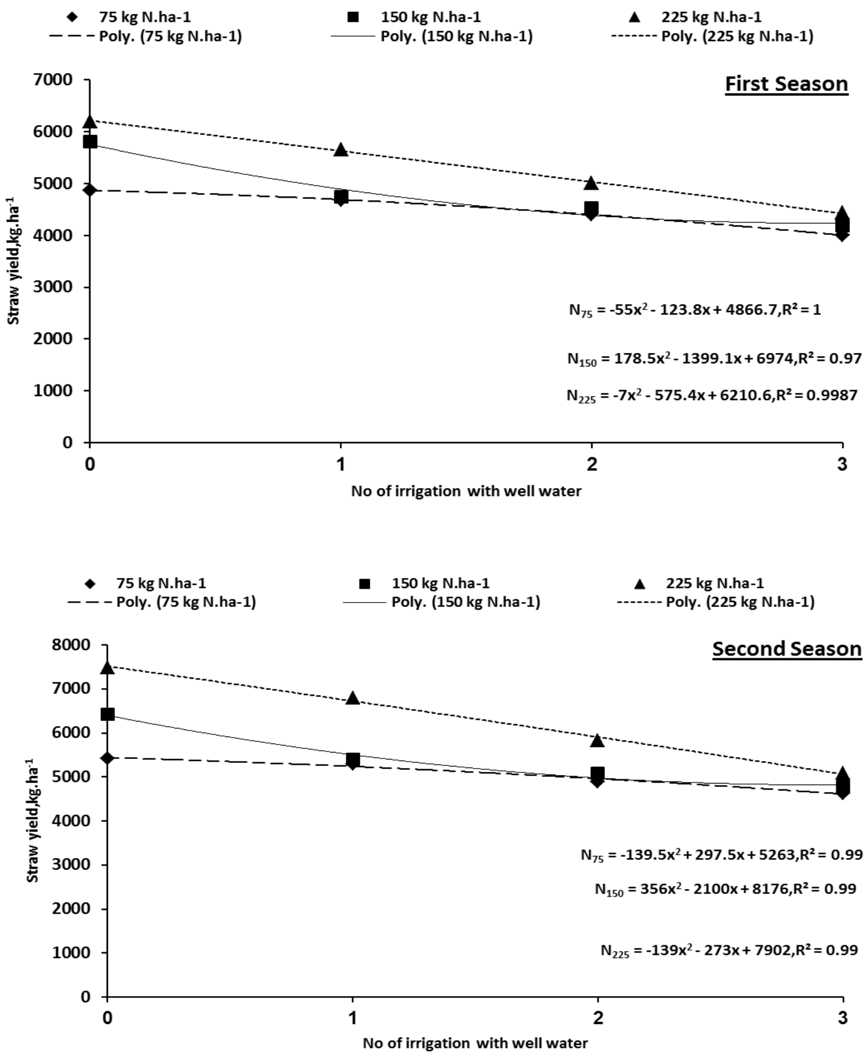


Fig.3: Polynomial quadratic models for straw of wheat crop grown on soil treated with different treatments of N fertilizer and irrigation in two successive seasons. One unit of irrigation = 2 times of irrigation with well water.

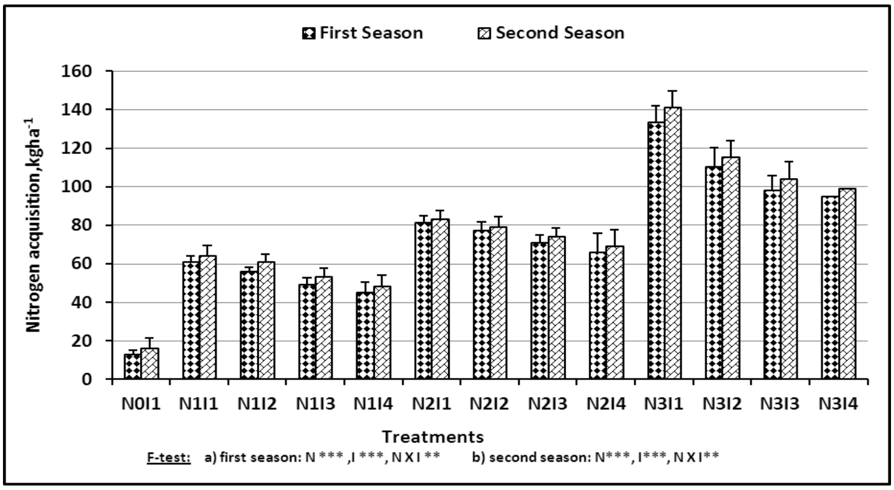


Fig.4: Nitrogen acquisition of wheat plants grown on soil treated with different treatments of N fertilizer and irrigation in two successive seasons.

Nitrogen use efficiency(NUE):

The mean values of NUE for grain yield were 63.73, 61.87, 57.49 and 53.07 kg grain Kg^{-1} N for 75 kg $N.ha^{-1}$ at different irrigation treatments N_1I_1, N_1I_2, N_1I_3, and N_1I_4, respectively for the first season (Table 4). The NUE decreased significantly with the increase in nitrogen application rate ($LSD_{0.05}$ = 0.58).At 150 kg $N.ha^{-1}$ NUE significantly decreased with increasing number of irrigation with well water (Table 4).

Table (4): Nitrogen use efficiency (NUE) for grain and straw of wheat plants grown on soil treated with different treatments for two seasons.

Treatments	NUE,kg yield.kg fertilizer^{-1}			
	Grain		Straw	
	First season	Second season	First season	Second season
N1I1	63.73(3.12) [a]	64.89(6.01)	69.47(4.98)	72.28(4.54)
N1I2	61.87(2.36)	62.49(2.77)	68.47(3.58)	70.67(3.81)
N1I3	57.49(1.88)	58.67(3.37)	64.43(4.98)	65.33(1.95)
N1I4	53.07(2.86)	53.33(2.46)	60.28(4.54)	61.76(2.93)
N2I1	37.69(0.44)	38.67(3.12)	42.67(2.22)	42.88(3.44)
N2I2	31.33(1.09)	31.67(2.22)	35.20(3.44)	36.00(2.45)
N2I3	29.33(0.98)	30.15(1.43)	33.33(2.43)	33.87(2.88)
N2I4	26.67(1.33)	27.91(1.66)	31.27(3.21)	31.91(3.65)
N3I1	26.53(0.98)	27.56(1.65)	31.64(1.99)	33.29(4.00)
N3I2	24.89(2.08)	25.16(2.23)	29.78(2.88)	30.22(2.12)
N3I3	22.13(1.11)	22.22(1.08)	25.33(3.32)	25.92(2.67)
N3I4	19.56(1.13)	19.70(1.43)	22.22(1.65)	22.91(1.88)
LSD 0.05	**0.58**	**0.61**	**0.88**	**0.91**

[a] Means of three samples (SD).

Similarly, NUE at 225 kg $N.ha^{-1}$ significantly reduced with the increase of number of irrigation with well water for the first season (Table 4).Also, for straw yield, NUE values were higher at 75 kg $N.ha^{-1}$ in comparison with 150 kg $N.ha^{-1}$ and 150 kg $N.ha^{-1}$ at all irrigation treatment for the first season (Table 4). The NUE values were significantly decreased ($LSD_{0.05}$ = 0.88) with increasing in nitrogen application rates and the increase of number of irrigation with well water at the same N application rate (Table 4). The values of NUE for the straw yield were much greater than those of grain yield at the same irrigation treatment for first season (Table 4). It is clear that irrigation with well water, however, decreased NUE for grain or straw yields noticeably ($P \leq 0.05$) at all N application rates (Table 4). The reduction in NUE for grain or straw yields of wheat was much higher at treatment I_4 (6 times well water ,4500 m^3ha^{-1}+ canal water, 1500 m^3ha^{-1}) than of that at treatment I_2(2 times well water,1500 m^3ha^{-1}+ canal water, 4500 m^3ha^{-1}). The maximum NUE for grain yield (63.73 kg. kg^{-1} N) was observed with a 75 kg $N.ha^{-1}$ and canal water-irrigated plots (N_1I_1). In contrast, the minimum NUE for grain yield (19.56kg. kg^{-1} N) was found with a 225 kg $N.ha^{-1}$ and 6 times well water-irrigated plots (N_3I_4). However, the maximum NUE for straw yield (69.47 kg. kg^{-1} N) was found with a 75 kg $N.ha^{-1}$ and canal water-irrigated plots (N_1I_1). In contrast, the minimum NUE for straw yield (22.22 kg. kg^{-1} N) was recorded with a 225 kg $N.ha^{-1}$ and 6 times well water-irrigated plots (N_3I_4). The mean nitrogen use efficiency(NUE) for grain and straw yields for the second season confirmed the results of the first season and were very close to each other (Table 4).

Agronomic efficiency(AE):

The rate of 225 kg N ha^{-1} have the minimum agronomic efficiency (AE) among N treatments, although the values of AE was varied with N treatments, but there was a tendency that AE was decreased with increasing N fertilizer inputs(Table 5).

Table (5): Agronomic efficiency (AE) for grain of wheat plants grown on soil treated with different treatments for two seasons.

Treatments	AE, kg yield.kg $fertilizer^{-1}$	
	First season	Second season
N1I1	39.20(1.44) [a]	39.88(2.55)
N1I2	37.33(3.12)	37.48(3.22)
N1I3	32.96(3.55)	33.65(2.88)
N1I4	28.53(2.09)	28.32(2.13)
N2I1	25.43(1.33)	26.16(1.12)
N2I2	19.07(1.08)	19.16(2.09)
N2I3	17.07(2.08)	17.65(1.09)
N2I4	14.40(1.12)	15.41(1.67)
N3I1	18.36(1.11)	19.22(2.04)
N3I2	16.71(1.09)	16.82(1.33)
N3I3	13.96(2.00)	13.88(1.08)
N3I4	11.38(0.98)	11.36(0.88)
LSD 0.05	**0.71**	**0.81**

[a] Means of three samples (SD).

However, the rate of 75 kg N ha^{-1} has the maximum agronomic efficiency (AE) among N treatments (Table 5). There was a significant effect of irrigation treatments on AE in both seasons ($LSD_{0.05}$ = 0.71 and 0.81 for first and second seasons respectively). Similarly, irrigation by well water decreased AE for grain yield noticeably ($P \leq 0.05$) at all N application rates (Table 5). The reduction in AE for grain yield of wheat was much higher at I4 treatment than of that at I2 treatment. The maximum AE for grain yield (39.20 kg. kg^{-1} N) was found with a 75 kg $N.ha^{-1}$ and canal water-irrigated plots (N_1I_1). In contrast, the minimum AE for grain yield (11.38 kg. kg^{-1} N) was found with a 225 kg $N.ha^{-1}$ and 6 times well water-irrigated plots (N_3I_4). The mean agronomic efficiency (AE) for grain yield for the second season confirmed the results of first season and was very close to each other (Table 5).

DISCUSSION

Statistical analysis showed that the highly significant interaction between N and irrigation treatments indicated that the grain and straw yields of wheat plants were dependent on number of irrigation with well water and nitrogen application rate. The depressive effect of well water irrigation times altered with canal water on grain and straw yields could be attributed to other factors such as suppression of root growth (Robertson, 1985; Gajwska and Sktodowska, 2009), imbalance in plant nutrition because of salinity stress and water stress (Catalado *et al.,* 1978) or a combination of these effects .Irrigation treatments and application of Nitrogen and their interaction significantly affected grain and straw yields of wheat plants (Fig.1). These results coincide with the results of Cartagena *et al.*,(1995) ; Hussain *et al.*,(1996); Schaan *et al.*,(2003); Choudhary *et al.*,(2006) and Wang *et al.*,(2010).

The values of coefficient of determination (R^2) and standard error of estimate (SE) indicated that the relationships between units of irrigation with well water and grain or straw yields were successfully described with polynomial quadratic model.

Because the adverse effects of well water irrigation on yield and straw yields of wheat plants, the I_{max} were negative values at Y_{max} resulting in 225 kg $N.ha^{-1}$ consequently would need more canal water application. These results coincided with the results of Fathi and Shama (2010).

Increasing nitrogen application rates at all irrigation treatments significantly increased N accumulation in grain or straw of wheat plant. Similar results were found by Abdel Magid *et al.* (1995) for wheat, Phillips *et al.* (2002) for bean, Clark *et al.* (1999) Colla *et al.* (2002) for tomato, Mahdy (2009) for maize, and Fathi and Shama(2010) for maize. The values of NUE for the straw yield were much greater than those of grain yield at the same irrigation treatment for first season. This was attributed with high straw yield at all irrigation water treatments (Table 4)**.**

The average values of AE ranged between 11.38 and 39.20 kg grain.kg^{-1} fertilizer for the first season and ranged from 11.36 to 39.88 kg grain.kg^{-1} for the second season (Table 5). These values were low as compared with the results of other's (Fang *et al.*2006; Yang *et al.* 2006). Optimization of water and N management requires knowledge of crop water requirements, N demands and the interaction between soil N dynamics and crop N uptakes. Determination of optimal irrigation regimes and N application rates is needed to increase GY and decrease the risk of N loss.

Conclusion

The optimum grain yield was achieved with application of 225 kg N ha^{-1} in combination with full irrigation with canal water which can give the best grain or straw yields, N accumulation, NUE, and AE in both seasons. The recommendation should be for those farmers who use the upper range of the recommended 150–400 kg N ha^{-1} which by MALR and accordingly can save about 25% of their N and 33% of their irrigation water application by adopting 225 kg N ha^{-1} (N_3) and irrigation with two times of well water as a supplemental irrigation combined with four times of canal water (I_2).

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التأثير المتداخل لمعاملات الرى المختلفة و التسميد النيتروجينى على محصول و امتصاص وكفاءة استخدام النيتروجين و الكفاءة المحصولية لنبات القمح

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أجريت دراسة حقلية بهدف دراسة التأثير المتداخل لمعاملات الرى المختلفة و التسميد النيتروجينى على محصول القمح(الحبوب و القش) و كذلك وصف العلاقة بين معاملات الرى و محصول القمح عند معدلات اضافة النيتروجين المختلفة بأستخدام معادلة الدرجة الثانية. أشارت النتائج الى وجود زيادة معنوية فى محصول الحبوب و القش بزيادة معدل اضافة النيتروجين عند كل معاملات الرى وكذلك حدوث انخفاض معنوى للمحصول بزيادة عدد الريات من مياة البئر. وكانت أقصى قيمة لكفاءة استخدام النيتروجين عند معدل تسميد نيتروجينى قدرة 75 كيلوجرام نيتروجين لكل هكتار و الرى بمياة الترعة و على العكس من ذلك وجد أن أقل قيمة لكفاءة استخدام النيتروجين قد وجدت عند معدل تسميد نيتروجينى 225 كيلوجرام نيتروجين لكل هكتار و الرى بمياة البئر. كما أن الرى بمياة البئر أدى الى انخفاض الكفاءة المحصولية لكلا من الحبوب و القش عند كل اضافات من النيتروجين وكان معدل الأنخفاض عند الرى بمعدل 4500 م3 لكل هكتار أكبر من الأنخفاض عند الرى بمياة البئر بمعدل 1500 م3 لكل هكتار.كذلك تشير نتائج الدراسة أنة تحت ظروف عدم توفر المياة العذبة لرى القمح فأنة يمكن استخدام هذا الماء العذب للرى فى الفترات الأولى لنمو النبات على أن يدعم الرى فيما بعد بمياة البئر عند المراحل المتأخرة من النمو.

قام بتحكيم البحث

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