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EFFECTS OF DIFFERENT NITROGEN FERTILIZERS AND HUMIC ACID ON WHEAT CROP IRRIGATED WITH DIFFERENT WATER REGIME USING ^{15}N

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Abstract

A field experiment was conducted to observe effects of water requirements and different fertilizers on wheat crop's yield, production and N uptake. Data showed that dry matter yield of wheat grain was higher with Hu + AS (5.82 mt/ha) compared with applied water 100% ET_C. Concerning the rate of water regime, the best significant grain yield of wheat was obtained with 100% ETc (4.23 mt/ha). Nitrogen derived from fertilizer Ndff% with 50% ET_C of water was 28.41 and 27.28% for grain and straw, respectively. At 100% ET_C of water the Ndff% was 30.16 and 27.75% for grain and straw, respectively. Nitrogen utilized by grains and straw was more efficient under treatment Hu + AS combined with 50% Etc, 100% Etc recording 15.6 and 32.23%, respectively. At 50% ET_C of water requirements for wheat crop, higher N remained in 0 - 15, 15 - 30 and 30 - 45 cm soil depth were nearly closed to each other compared with the treatment made at 100% ET_C of water requirements.

Introduction

Wheat (*Triticum aestivum* L., Family: Poaceae) is one of the most important crops, providing over 20% of the calories consumed by the world's population (Braun *et al.* 2010). It is an important crop in irrigated perimeters of the arid region (Rathore *et al.* 2016).

Fertilizer application is one way to control and improve yield and nutritional quality of crops for human consumption. In the current food production scenario across major cropping systems of the world, crop yield is limited significantly by availability of nitrogen (N) and water resources rather than the crop genetics (Sinclair and Rufty 2012).

Addition of humic substances has been shown to improve aggregation in soils with a range of texture grades and mineral adjustments (Quilty 2011). The cation exchange capacity of the soil is also impacted by the application of humic substances. Humus generally accounts for 50 - 90% of the cation-absorbing power of mineral surface soils. Like clays, humus colloids hold nutrient cations i.e. potassium, calcium, magnesium, in easily exchangeable form, wherein they can be used by plants but are not too readily leached out of the profile by percolating waters (Hama *et al.* 2011, Lillo *et al.* 2013).

The main objective of this work was to investigate the effect of water regime and fertilizer types on wheat production and nitrogen distribution in soil profile using ^{15}N technique under wheat plants grown in sandy soil.

Materials and Methods

A field experiment was conducted at the Soils and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt. A new variety of wheat (*Triticum aestivum* cv. Giza-171) was used as test crop grown on sandy soil which have 88.5% sand with

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2.7% silt and 8.8% clay; pH (1 : 2.5) 7.97 and electrical conductivity (EC) 0.27 dS/m; organic content (OC) 170 mg/kg, organic matter (OM) 0.3 g/kg, total nitrogen (TN) 70 mg/kg, carbon : nitrogen ratio (C/N) 2.4 and calcium carbonate ($CaCO_3$) 10 mg/kg. Fertilization treatments were distributed in factorial randomized complete block design with three replicates under drip irrigation system. Fertilizer rate was divided into three equal doses and applied through the drip irrigation system (fertigation). The three splits were applied at 21, 51 and 81 days after sowing Some of the chemical properties of irrigation water are listed in Table 1.

Table 1. Physico-chemical properties of irrigated water used in the experiment.

pH	EC (dS/m)	SAR	Soluble ions (mmol/l)						
			Cations				Anions		
			Mg^{2+}	Ca^{2+}	K^+	Na^+	HCO^{3-}	SO_4^{2-}	Cl^-
7.53	0.38	2.8	0.51	1.32	0.22	2.13	0.33	1.54	2.31

The water was delivered via 50 mm diameter poly ethylene (PE) main pipe through a control head involving media and screen filters. Fertilizer injector (19 mm venturi) was fitted with valves and pressure gauges. Two drip irrigation plots connected with 16 mm diameter PE laterals served to provid two different water regimes. Each plot includeds 18 laterals having 0.5 m spacing between laterals. Each lateral had online emitters at 0.5 m apart along the lateral line. Each plot with 1.5×2.4 m^2 consists of 18 laterals where fertilization treatments applied.

The experimental protocol has been presented in Table 2. There were 2 main treatments (A and B) under each of which 6 sub-treatments were run (Table 2). The main plots were divided into two sections which included two different water regimes.

Table 2. Showing the experimental protocol.

Sl. no.	Experiment title	Meaning	Abbre-viation	Application amount
A	W1	50% water requirements	50%ETc	4844 m^3
B	W2	100% water requirements	100%ETc	9688 m^3
1	C	Control	-	No fertilizer added
2	Hu	Humic acid	-	1.2 kg/ha
3	AN	Ammonium nitrate	-	180 kg/ha
4	AS	Ammonium sulphate	-	180 kg/ha
5	50% Hu + 50% AN	Humic acid and ammonium nitrate	-	0.6 + 90 kg/ha
6	50% Hu + 50% AS	Humic acid and ammonium sulphate	-	0.6 + 90 kg/ha

The $^{15}N/^{14}N$ ratio was determined by emission spectrometry ^{15}N-analyzer (Model NOI-6PC, Germany) following the description of International Atomic Energy Agency (IAEA 2001). Various percentage fractions of nitrogen derived from fertilizer (Ndff), fertilizer use efficiency (FUE), fertilizer-N remained in soil and fertilizer-N losses were calculated according to Hardarson and Danso (1990). Chemical and physical analysis of experimental soil samples was carried out according to Page *et al.* (1982) and Black (1965).

Data collected were statistically analyzed as a factorial complete block design with nine replications using analysis of variance to evaluate main and interaction effects as described by Snedcor and Cochran (1982). Means among treatments were compared using LSD at p = 0.05 probability.

Results and Discussion

The yield of grain dry matter was affected significantly by fertilization types and water regime (Table 3). Grains yield was higher with combined treatment of Hu + AS (5.82 mt/ha) than individual treatment of As (5.26 mt/ha), Hu + AN (5.11 mt/ha), AN (4.88 mt/ha), Hu 2.38 mt/ha and control (1.93 mt/ha) under 100% ET_C water regime. Concerning water regime. the best significant grains yield was obtained under 100% ET_C (4.23 mt/ha). The highest value of grain yield achieved with Hu + AS was 5.82 mt/ha. The usefulness of crop water indicators to assess crop growth, productivity and soil water status demonstrates the potential of various spectral processing methods for retrieving crop water contents from canopy reflectance spectrums (Zhang *et al.* 2018a).

Dry matter yield of straw was affected significantly by fertilization types and water regime (Table 3). Straw yield was higher with AN (5.96 mt/ha) than those of Hu + AN (5.79 mt/ha), AS (5.79 mt/ha), Hu + AS (5.52 mt/ha), Hu (3.37) mt/ha and control (1.94 mt/ha) when 100% ET_C water regime was applied. Concerning the rate of water regime, the best significant straw yield was obtained with 100% ET_C (4.73 mt/ha). Interaction between fertilizers types versus water regime resulted in the highest value AN (5.96 mt/ha) straw yield. The mixed sowing irrigation and splitting nitrogen to the big flare stage could increase not only grain yield, but also resource use efficiency under straw retention (Zhang *et al.* 2018b).

Table 3 **Effects of water regime and fertilizer types on wheat dry matter yield (mt/ha)**

Water regime (W) 50%			
Treatment (T)	Grains	Straw	Total biomass
Control	1.38	2.29	3.67
Hu	1.70	2.86	4.56
AN	2.13	2.56	4.68
AS	3.69	5.42	9.11
Hu + AN	3.73	4.92	8.66
Hu + AS	3.12	5.36	8.48
Mean	2.63	3.90	6.53
Water regime (W) 100%			
Control	1.93	1.94	3.87
Hu	2.38	3.37	5.74
AN	4.88	5.96	10.84
AS	5.26	5.79	11.06
Hu + AN	5.11	5.800	10.90
Hu + AS	5.82	5.52	11.33
Mean	4.230	4.73	8.96

Grains: LSD 0.05 = T: 0.36, W, 0.36, T*W: 0.63;
Straw: LSD 0.05 = T: 0.34, W: 0.34, T*W: 0.60.

Nitrogen uptake was higher in the grains of wheat than in the straw (Table 4). The N yield (kg/ha) in different plant parts were significantly different among the treatments. Although higher values were obtained in Hu + AS, Hu + AN treatment with grains and straw (83.77) and 47.05 kg/ha), respectively when 100% ET_C was applied compared with all the treatments. Nitrogen uptake by crop depends on both soils N supply and crop growth, and soil water content affects both the availability of N and crop growth (Gonzalez-Dugo *et al.* 2010). Nitrogen uptake in grains was lower for control (14.273 kg/ ha), and Hu (23.080 kg /ha) and AN (51.72 kg/ha). N uptake in straw yield had a similar trend with grains. Concerning the rate of water regime, significant grain and straw yield of wheat were achieved with 100% ET_C (50.39 and 39.63 kg/ha) compared to those recorded for 50% ET_C of water (32.06 and 32.96 kg/ha). Interaction between fertilizer types and water regime resulted in the highest grain yield at Hu + AS (83.77 mt/ha). Albina *et al.* (2013) reported that irrigation is the main factor affecting nitrogen uptake, translocation, distribution and accumulation in winter wheat. Rathore *et al.* (2017) showed that the irrigation levels and N rates are two of the most important factors for optimizing yield, water productivity and nitrogen-use efficiency of wheat in arid regions.

Table 4. Effects of water regime and fertilizer types on N uptake kg/ha of wheat crop.

Treatment (T)	Water regime (W) 50% ET_C		
	Grains	Straw	Mean
Control	10.38	11.20	21.59
Hu	21.27	23.46	44.73
AN	25.07	22.00	47.07
AS	46.50	47.13	93.63
Hu + AN	47.05	46.77	93.81
Hu + AS	42.09	47.200	89.29
Mean	32.06	32.96	65.02
	Water regime (W) 100% ETC		
Control	14.27	11.07	25.35
Hu	23.08	24.23	47.31
AN	51.72	45.89	97.61
AS	61.56	54.43	115.99
Hu + AN	67.96	48.68	116.63
H + AS	83.77	53.46	137.23
Mean	50.39	39.63	

Grain; LSD 0.05 = T:1.75, W, 1.75, T*W: 3.02; straw: LSD 0.05 = T: 0.80, W: 0.80, T*W: 1.61.

The percentage of N uptake from fertilizer by grain was higher than that of straw under all treatments (Table 5). Plants irrigated with 100% Et_C indicated the highest %Ndff by either grain or straw. In this regard, application of combined treatment Hu + AS resulted in high percentages of N derived from fertilizer accounted for 34.65 and 29.03% by grain and straw, respectively. Despite of fertilization treatments, the mean values of %Ndff were slightly higher in case of 100% Etc than those of 50% Et_C. This was true for grains and straw. Comparison between fertilization treatments indicated the following ranking, Hu + AS > Hu + AN > AS > AN, for either grains or straw. Kim *et al.* (2008) reported that synergistic relationships exist between water and nitrogen and revealed that both of them has positive effects on each other. Nitrogen use efficiency was frequently affected by N fertilizer type and water regimes (Table 5). Nitrogen used by straw was more efficient with combined Hu + AS treatment under 50% ET_C, and 100% ET_C recording 17.36 and 18.74%, respectively. Nitrogen used by grains was nearly closed to those of straw and became more efficient under Hu + AS combined treatment in conjunction with 50% ET_C, while it was 15.60 and 32.23% under 100% ET_C for the same sequence. NUE of grains was significantly higher than those recorded with straw under 100% ET_C of water; but reversible trend was noticed under 50% ET_C. The adoption of an appropriate deficit irrigation and N rate combination can be an effective means to reduce non-beneficial water consumption, achieve higher yield, and improve water productivity (WP) and NUE for wheat in an arid environment (Rathore *et al.* 2017).

Table 5. Effects of water regime and fertilizer types on %Ndff, Nddf kg/ha, %NUE.

Treatment (F)	Water regime (W) 50% ET_C					
	% Ndff		Nddf (kg/ha)		% NUE	
	Grains	Straw	Grains	Straw	Grains	Straw
AN	19.5	18.0	4.89	3.96	2.7	2.2
AS	28.0	31.5	13.02	14.85	7.2	8.3
Hu + AN	33.05	26.5	15.45	12.39	13.77	13.77
Hu + AS	33.35	33.1	14.04	15.62	15.6	17.36
Mean	28.41	27.28	11.702	11.705	9.82	10.41
	Water regime (W) 100% ET_C					
AN	21.0	18.3	10.86	8.40	6.03	4.7
AS	32.0	30.5	19.70	16.60	10.94	9.22
Hu + AN	33.0	30.65	22.43	14.92	24.92	16.6
Hu + AS	34.65	31.55	29.03	16.87	32.23	18.74
Mean	30.16	27.75	20.51	14.18	18.53	12.31

Fertilizer-nitrogen remained in soil was distributed in the soil profile from 0 - 45 cm depth, and significantly affected by fertilization types and water regime (Fig. 1). Under 50%ET_C of water regime, high fertilizer-N was remained in 0 - 15 cm, while those recorded in 15 - 30 cm and 30 - 45 cm were nearly closed to each other. These values, in general, were higher than those achieved under 100%ET_C water regime. Generally, N remained in soil was higher in case of individual fertilization of AN or AS than combined treatments.

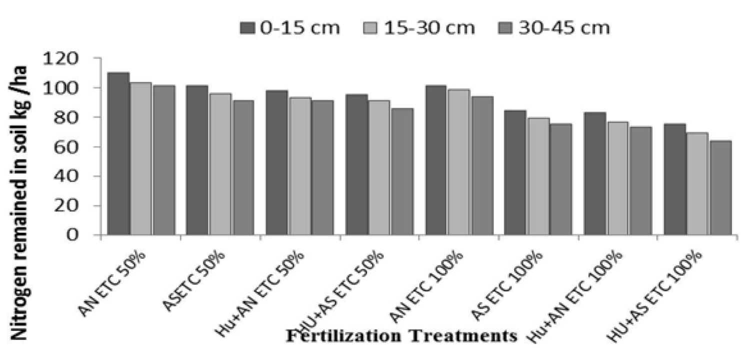

Fig. 1. Effects of water regime and fertilizer types on fertilizer-nitrogen in soil profile.

Nitrogen remained in soil was localized, to some extent in 20 - 40 and 40 - 60 cm when full dose of mineral fertilizer was applied. Also, the combined treatment of 50% compost + 50% mineral fertilizer showed accumulation of remained-N in the top layer 0 - 20 cm while the quantities remained in 20 - 40 and 40 - 60 cm were nearly close to each other (Ghabour *et al.* 2015).

In this study, the grains yield of wheat crop was significantly varied according to fertilizers types and water regimes. In this regard, grain yield of plants irrigated with 100%Et_C was higher in case of humic acid combined with ammonium sulfate (Hu + AS) (5.817 ton/ha) than those of other treatments. These values of grain yield surpass those recorded under 50%Et_C for the same fertilization treatment. Nitrogen use efficiency was frequent according to plant parts and water regimes. For NUE by grain was significantly higher than those recorded for straw under100% ET_C while reversible trend was noticed under 50% ET_C. Nitrogen remained in soil after harvest was slightly higher in case of 50%Et_C than those recorded with 100%Etc water regime. Generally, N remained in soil was decreased under combined treatments of humic acid with either ammonium sulfate or ammonium nitrate comparing to individual fertilization treatments. All treatments reflected high accumulation of fertilizer-N remained in the surface 15 cm. These values tended to decrease gradually at 15 - 30 and 30 - 45 cm depth.

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