Menoufia J. Soil Sci., Vol. 1 August (2016): 77 - 91

RESPONSE OF WHEAT GROWN ON OLD - CULTIVATED SOIL TO LIQUID AMMONIA FERTILIZATION AND WATER MANAGEMENT VIA DIFFERENT LEVELS OF SOIL MOISTURE DEPLETION

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Received: May 17, 2016 **Accepted: Jun. 28, 2016**

ABSTRACT: *Field experiment was carried out at Fayoum Agric. Res. Station, Tameia, Fayoum Governorate, Egypt. during 2013/14 and 2014/2015 winter seasons to study the effect of 80 and 100 kg N fed^{-1} (as liquid ammonia, 82.4 % N) and irrigating at 40, 60 and 80% of total available soil moisture were depleted (ASMD) on yield, yield components and some crop - water relations of wheat (Giza 168). A split plot design with four replications was applied, where N rates were assigned to main plots, whereas irrigation regimes were arranged in the split plots. The obtained results exhibited that:*

**Wheat grain and straw yields as well as yield components i.e. plant height, spike number m^{-2} and 1000-grain weigh were significantly affected by N fertilizer rates, irrigation regimes and their interaction in 1st and 2nd seasons. Applying 100 kg N fed^{-1} and/or irrigating at 40% ASMD regime exhibited the highest values of the abovementioned parameters.*

** Applying 100 kg N fed^{-1} and/or irrigating at 40% ASMD regime exhibited higher water use (Cu) values, whereas, 80 kg N fed^{-1} and/or irrigating at 80% ASMD regime resulted in the lowest values at 1st and 2nd seasons. The values of daily ET_C was increased with increasing N rate, and the same trend was observed with irrigating at 40% ASMD regime and such findings were recorded in the two seasons of study. Reducing N rate from 100 to 80 kg Nfed^{-1} decreased the K_C values during the entire growing seasons, and increasing the SMD from 40 to be 60 or 80% exhibited similar trends 1st and 2nd seasons.*

** Values of WUE, as a function of N fertilization rates and irrigation regimes, were 1.25 and 1.22 kg grain m^{-3} water consumed at 1st and 2nd seasons, respectively. Applying 100 kg N fed^{-1} resulted in higher WUE values which comprised 1.26 and 1.23 kg grains m^{-3} water consumed at 1st and 2nd seasons, respectively. Irrigating wheat crop at 40% ASMD regime resulted in the highest WUE values, which reached to 1.28 and 1.25 kg grains m^{-3} water consumed at 1st and 2nd seasons, respectively. The interaction data reveal that the highest WUE values (1.29 and 1.26 kg grains m^{-3} water consumed) were occurred with 100 kg Nfed^{-1} rate as interacted with 40 % ASMD regime in 1st and 2nd seasons, respectively,*

Key words: *Wheat grain yield and yield components, fertilizing with liquid ammonia, irrigation regime, water consumptive use, water productivity*

INTRODUCTION

Wheat is grown under irrigation in the tropics either in the highlands near the equator and in the lowlands away from the equator. In the subtropics with summer rainfall the crop is grown under irrigation in the winter months. In the subtropics with winter rainfall it is grown under supplemental irrigation, FAO (2015). Wheat is the most strategic cereal crop and considered the main food for Egyptian people, however, its production does not meet the current demands. So, unusual efforts must be exerted, concerning proper inputs, in particular, water and N fertilizer management in order to mitigate the gap between production and consumption.

All crops require nitrogen (N) for the production of a photosynthetically active canopy, whose functionality will strongly influence the crop performance. Wheat is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization. The nitrogen supply to the plant will influence the amount of protein, protoplasm and chlorophyll formed. In turn, this influences cell size and leaf area, photosynthetic activity and consequently the final economic yield. Although greater N application has produced higher yields, this is not a linear relationship and there is an economic optimum application offsetting incremental yield increase against the cost of additional N inputs, which needs to be determined for individual cultivars (King *et al.,* 2003). Anhydrous ammonia, urea, ammonium sulfate and ammonium nitrate are the most frequently used N fertilizers in Egypt. The interaction of source and rate of such fertilizers did not significantly influenced either wheat yield or its components, Shams El-Din *et al.* (1990). So, from an economic standpoint, anhydrous ammonia is preferable as N source in order to reduce N fertilization costs. In connection, Dencic *et al.* (2011), Asif *et al.* (2012), Ahamad and Abolfazl (2013), El-Akram and Emam (2014), Mandic *et al.* (2015) and Ayed *et al.* (2016) recorded increased grain yield and its components with increase in nitrogen level. Furthermore, Wang *et al.* (2012) reported that the average wheat grain yield of 221 kg N ha^{-1} were found to be 99.1, 45.1, 20.0 and 7.4 % higher than those of 0, 79, 140 and 300kg N ha^{-1}, respectively. The 221 kg N ha^{-1} had the highest WUE (4.75 kg ha^{-1} mm^{-1}) among all N treatments. In connection, Shaaban (2006) found that the maximum values of water use efficiency (WUE) for grains and straw yields of wheat plants were observed by increasing doses of inorganic N fertilizer. In 2 – season field experiment with wheat, Abdelkhalek *et al.* (2015) reported that 90 kg $Nfed^{-1}$ rate, as anhydrous ammonia, slightly increased Cu (2.38 – 2.44 %) and insignificantly increased grain yield, whereas water productivity revealed different trends in the two seasons, comparable with 75 kg $Nfed^{-1}$ one

In Egypt, due to the prevailing arid climate, irrigation is the most important input for crops production and the irrigation water shortage affects strongly both the productivity and profitability of the crops. Plant and crop responses to water are generally depend on the availability of other inputs, such as nutrients, sunshine and practices management, Zoebl (2006), Passioura (2006), Molden *et al.* (2010) and Zwart *et al.* (2010). In Egypt, Yousef and Ashry (2006) found that the highest yield and yield components resulted from irrigating wheat at 35% ASMD and increasing ASMD to 55 or 75 % caused significant reduction in grain and straw yields and yield components as well. Seasonal ET_C values were: 43.13, 40.12 and 39.05 cm for irrigation at 35, 55 and 75 % ASMD, respectively. The peak of water consumption occurred during February and March and the K_C values were 0.53, 0.74, 0.87, 0.91, 0.99, 0.60 and 0.41 for Nov., Dec., Jan., Feb., Mar., Apr. and May, respectively. Yordanov *et al.* (2003) reported that drought generates unfavorable and unaffordable changes in plants resulting in growth and photosynthesis inhibition affecting yield components adversely. The authors added that rapid inhibition of shoot and limited root growth are the symptoms induced by drought which are further characterized by stomatal closure resulting in transpiration rate and CO_2 uptake reduction during photosynthesis. In 2 – season field experiment. Mahamed *et al.*

(2011) reported that 50% Soil Moisture Depletion (control) gave the highest grain yield, 1000 – seed weight, spike length, plant height and WUE at each growth stage. Increasing the SMD level significantly reduced the yield and yield components of the "Hawi" bread wheat. Grain yield reduction was 26.6 and 30.8% for 60 and 75% SMD of available soil water, respectively, compared with the control. Wang *et al.* (2012) found that significant effect was observed on wheat grain yield, kernel numbers and straw yield due to irrigation levels e.g. 0.6, 0.8 and 1.0 of the estimated evapotranspiration-ET and the highest values were achieved with a high irrigation supply, although WUE generally decreased linearly with increasing seasonal irrigation rates. In 2 - year trial, Abdelkhalek *et al.* (2015) found that the highest Cu for wheat crop (47.78 – 56.48 cm) was recorded with 5 irrigation events, and the value tended to reduce to be (41.91 – 48.72 cm) and (37.0 – 40.68 cm) with 4 and 3 irrigation events, respectively. The authors added that water productivity exhibited an opposite trends, where the highest figures were noticed with 3 irrigation events and gradually decreased with 4 and 5 irrigation events. Tari (2016) studied the effect of 22 experimental treatments, including full irrigation and dry treatments and water-deficit levels (0, 35, 65 and 100%) at different growth stages of wheat (stem elongation, heading and milk stage). Data indicated that seasonal water-consumptive use of experimental treatments varied between 206 and 571 mm; the grain yields varied between 288 and 682 kg da^{-1}; 1000 – kernel weights varied between 33.9 and 52.2 g; the total water-use efficiencies varied between 1.02 and 1.30 kg m^{-3} and irrigation water-use efficiencies varied between 0.51 and 1.17 kg m^{-3}.

The present research aims to find out the most proper interaction of two liquid ammonia rates and irrigation based on different soil moisture depletion levels on the yield and water productivity for 168 wheat variety grown at Fayoum Governorate.

MATERIALS AND METHODS

The present investigation was conducted during 2013/14 and 2014/15 winter seasons at Fayoum Agric. Res. Station, Tameia, Fayoum Governorate, Egypt. Physical and chemical soil properties of the experimental site were determined according to Klute (1986) and Page *et al.* (1982) and data are presented in Table (1). In addition, some soil moisture constants, as gravimetrically determined on oven dry basis, in15 cm increment system from soil surface and down to 60 cm depth and data are recorded in Table (2). The experiment aimed to study the effect of two levels of N fertilization i.e. 80 and 100 kg N fed^{-1} (as liquid ammonia, 82.4 % N) and three irrigation regimes e.g. irrigating when 40, 60 and 80 % of available soil moisture were depleted (ASMD) and their interaction on wheat yield, yield components and some crop - water relations.

The applied treatments were arranged in a split-plot design with four replicates. The main plots were allocated for N fertilization rates while the split ones were assigned for the irrigation regimes. The sub-plots area was 21 m^2 (3 x 7 m) and each plot was separated from the others by allays 1.5 m in between to reduce the lateral movement of water. Calcium super phosphate (15.5% P_2O_5) at 150 kg fed^{-1} rate was incorporated into the soil surface during seed bed preparation. The N fertilization rates, as liquid ammonia, were injected into the soil and the recommendations e.g. injection timing, injection depth…..etc. were considered. Wheat seeds (Giza 168 Cv) were sown at 70 kg fed^{-1} rate on November 15th and 16th in 1st and 2nd seasons, respectively. Surface irrigation was adopted to convey the irrigation water to the experimental plots. Irrigation event, date and total irrigation count are recorded in Table (3).

Table 1: Particle size distribution and some chemical analysis of the experimental soil during 2013/14 and 2014/15 seasons (average of the two seasons)

Particle size distribution				Organic matter (%)	$CaCo_3$ (%)
Sand (%)	Silt (%)	Clay (%)	Textural class		
41.02	19.76	39.22	Clay loam	1.49	6.21

Soluble cations ($meqL^{-1}$)				Soluble anions ($meqL^{-1}$))				EC (dSm^{-1})	P^H(soil paste)	CEC (meq/100gsoil)	Exchangeable Cations (meq/100 g soil)			
Ca^{++}	Mg^{+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{--}	SO_4^{--}	5.48	8.39	39.17	Ca^{++}	Mg^{++}	K^{+}	Na+
9.32	6.91	33.19	0.61	25.19	4.15	-	20.69				19.31	12.11	1.32	6.19

Table 2: Soil moisture constants for the experimental site during 2013/14 and 2014/15 seasons (average of the two seasons)

Soil depth (cm)	Field capacity (%,wt/wt)	Wilting point (%wt/wt)	Bulk density (gcm^{-3})	Available moisture (%wt/wt)	Available moisture (mm)
00 -15	44.72	21.75	1.53	22.97	52.72
15 -30	41.32	19.32	1.42	22.00	46.86
30 - 45	37.21	18.41	1.29	18.80	36.38
45 - 60	35.29	17.67	1.31	17.62	34.10

Table 3: Irrigation date and total count under the applied irrigation regimes in 2013/14 and 2014/15 seasons

Irrigation event	2013/14			2014/15		
	Irrigation regimes (ASMD %)			Irrigation regimes (ASMD %)		
	40	60	80	40	60	80
Planting	15/11	15/11	15/11	14/11	14/11	14/11
Life irrigation	5/12	5/12	5/12	5/12	5/12	5/12
2^{nd} irrigation	25/12	30/12	3/1	24/12	29/1	3/1
3^{rd} irrigation	13/1	24/1	1/2	12/1	24/1	1/2
4^{th} irrigation	2/2	17/2	2/3	2/2	16/2	3/3
5^{th} irrigation	27/2	14/3	3/4	28/2	14/3	4/4
6^{th} irrigation	19/3	8/4	-	19/3	8/4	-
7^{th} irrigation	3/4	-	-	11/4	-	-
Harvesting	30/4	30/4	30/4	30/4	30/4	30/4
Irrigation count	7	6	5	7	6	5

At harvesting time the following parameters were recorded for each sub-plot.

I. Yield and yield components:

Plant height (cm), spike number m^{-2}, 1000-grain weight (g), grain yield (kg fed^{-1}) and straw yield (kg fed^{-1}). All the collected data were subjected to the statistical analysis according to Snedecor and Cochran (1980) and the means were compared by LSD test at 5% level.

II. Crop - water relationships:

Crop-water requirements are varied during the growing period, mainly due to variation in crop canopy and weather conditions, and tightly related to agricultural practices, cropping technique and irrigation methods. The correct knowledge of ETc allows improve water management by changing the volume and frequency of irrigation in order to meet the crop requirements and to adapt to soil characteristics.

1- Seasonal consumptive use (ET_C).

Water consumptive use was calculated as soil moisture depletion (SMD) according to Hansen *et al.* (1979) as follows:

$$CU = SMD = ET_C = (h2 - h1)/ 100 \times Dbi \times D$$

Where:

CU= Water consumptive use in the effective root zone (60 cm), cm,

h2 =Gravimetric soil moisture percentage by weight 48 h after irrigation,

h1 =Gravimetric soil moisture percentage by weight before the next irrigation,

Dbi= Soil bulk density (Mg m^{-3}) for the given soil layer,

Di= Soil layer depth (15 cm),

2. Daily ET_C rate (mm/day).

Daily ET_C rate was calculated from the ET_C between each two successive irrigations divided by the number of days.

3. Reference evapotranspiration (ET_0).

Reference evapotranspiration (ETo) reflects the impact of weather condition to the evaporation and transpiration. ETo was estimated as a monthly rate (mm day^{-1}), using the monthly averages of weather factors of Fayoum Governorate (Table 4) and the procedures of the FAO-Penman Monteith equation (Allen *et al.* 1998).

4. Crop Coefficient (K_C).

Crop coefficients are characteristics of plants used in predicting evapotranspiration (ET). The most basic crop coefficient, K_c, is simply the ratio of ET observed for the crop studied over that observed for the well calibrated reference crop (ET_o) under the same conditions. K_C was calculated according to Allen *et al.* (1998) as follows:

$$K_C = ET_C / ET_0$$ Where:

ET_C= Actual crop evapotranspiration (mmday^{-1})

ET_0= Reference evapotranspiration (mmday^{-1}).

5. Water use efficiency (WUE).

Water use efficiency was calculated according to Jensen (1983) as follows:

$$WUE = \frac{Y}{CU}$$

Where:

WUE = kg grains m^{-3} water consumed

Y = Grain yield (kgfed^{-1})

CU= Seasonal water consumptive use ($m^3 fed^{-1}$)

RESULTS AND DISCUSSION

I- Yield and yield components.

1- Yield components.

The results in Table (5) indicate that wheat yield components were significantly affected by the applied N fertilizer rates in 1st and 2nd seasons. Applying 100 kg N fed^{-1}

gave the highest values of yield components i.e. plant height, spike number m^{-2} and 1000-grain weight, which were higher than those with 80 kg N fed^{-1} by 4.52, 5.33 and 3.96% in 1st season and by 3.04, 2.69 and 3.52%, respectively, in 2nd season. These increments may be due to the role of nitrogen for stimulating amino acid building and growth hormones, which in turn acts positively on cell division and enlargement. These results are in harmony with those reported by Ahamad and Abolfazl (2013), El-Akram and Emam (2014).

Concerning the effect of the applied irrigation regimes, data show that the wheat yield components were significantly affected in 1st and 2nd seasons. The highest values of yield components e.g. plant height, spike number m^{-2} and 1000-grain weight were observed with the highest irrigation rate (irrigating as 40% of available soil moisture was depleted) and amounted to (100.07 and 97.62 cm), (425.55 and 411.06) and (45.65 and 44.82 g) in 1st and 2nd seasons, respectively. Irrigating at 60 or 80% ASMD resulted in lower values of the abovementioned yield components reached to (7.22 and 14.86 %), (5.36 and 15.77%) and (3.68 and 8.87%) in 1st season and to (7.65 and 15.27%), (2.73 and 18.74%) and (3.62 and 7.72%) in 2 season, comparable with 40% ASMD, respectively. Yordanov et *al.* (2003) reported that drought generates unfavorable and unaffordable changes in plants resulting in growth and photosynthesis inhibition affecting yield components adversely.

Data in Table (5) reveal that the wheat yield components were significantly affected by the interaction of N fertilization rates and soil moisture depletion (ASMD) regimes in 1st and 2nd seasons. The highest values of plant height, spike number m^{-2} and 1000-garin weight were recorded due to applying 100 kg N fed^{-1} and irrigating at 40 % ASMD in 1st and 2nd seasons,. On contrast, the lowest values of the abovementioned yield components resulted from applying 80 kg N fed^{-1} combined with irrigation at 80 % ASMD.

Table 4: The monthly averages of weather factors for Fayoum Governorate during 2013/2014 and 2014/2015 growing seasons

Month	Year	Temperature Cº			Relative Humidity (%)	Wind speed (m sec^{-1})	Class A pan evaporation (mm day^{-1})
		Max	Min	Mean			
November	2013	29.1	17.4	23.3	40	1.48	2.5
	2014	29.4	17.2	23.3	51	1.46	2.1
December	2013	23.7	11.6	17.8	45	1.05	1.6
	2014	26.1	12.6	19.4	51	1.10	1.5
January	2014	23.6	9.6	16.7	43	1.18	1.6
	2015	22.5	10.3	16.4	49	1.16	1.8
February	2014	25.8	11.1	17.6	45	1.65	2.4
	2015	23.6	10.5	17.1	49	1.55	2.3
March	2014	30.3	12.9	21.6	46	2.13	4.6
	2015	28.8	14.9	21.9	48	2.08	3.9
April	2014	30.4	15.4	23.1	43	2.43	4.4
	2015	32.8	15.7	24.3	45	2.37	5.5

Table (5): Effect of N fertilization rates and irrigation regimes and their interaction on yield and yield components of wheat crop in 2013/2014 and 2014/2015 seasons.

N rate (Liquid Ammonia) (F)	Soil Moisture Depletion (I)	Plant height (cm)	Spike N^{o}./m^{2}	1000-grain Weight (g)	Grain yield (kgfed^{-1})	Straw yield (kgfed^{-1})
2013/2014 season						
80 kg Nfed^{-1}	40%	98.61	411.6	44.61	2311.4	2628.3
	60%	91.22	396.8	43.12	2104.7	2291.6
	80%	82.13	347.5	40.94	1918.3	2012.2
Mean		90.65	385.30	42.89	2111.5	2310.7
100 kg Nfed^{-1}	40%	101.52	439.5	46.69	2414.6	2815.4
	60%	94.45	408.7	44.81	2231.5	2547.1
	80%	88.27	369.4	42.26	2070.8	2209.6
Mean		94.75	405.87	44.59	2239.0	2524.03
Irrigation mean						
40% SMD		100.07	425.55	45.65	2363.0	2721.85
60% SMD		92.84	402.75	43.97	2168.1	2419.35
80% SMD		85.20	358.45	41.60	1994.6	2110.90
Interactions						
F		0.54	9.1	0.72	23.1	22.0
I		0.70	4.9	0.93	18.4	23.5
F x I		0.83	6.5	0.88	14.5	25.0
2013/2014 season						
80 kg Nfed^{-1}	40%	96.35	400.51	42.96	2185.11	2496.72
	60%	89.45	399.69	41.39	2003.62	2173.49
	80%	80.97	329.69	40.15	1880.29	2106.50
Mean		88.92	376.63	41.50	2023.01	2258.90
100 kg Nfed^{-1}	40%	98.89	421.61	44.82	2322.82	2700.96
	60%	91.22	400.29	43.21	2111.91	2446.13
	80%	84.75	338.33	40.85	1943.27	2131.56
Mean		91.62	386.75	42.96	2126.00	2426.22
Irrigation mean						
40% SMD		97.62	411.06	43.89	2254.00	2598.84
60% SMD		90.34	399.85	42.30	2057.80	2309.81
80% SMD		82.86	334.01	40.50	1911.78	2026.69
Interactions						
LSD, 05	F	0.47	7.6	0.60	15.9	18.7
	I	0.43	7.1	0.61	17.6	17.1
	F x I	0.66	10.1	0.81	16.0	21.0

2- Grain and straw yields

Application of N fertilization rates or irrigation regimes significantly influenced wheat grain and straw yields in1st and 2nd seasons, Table 5. Applying 100 kg N fed^{-1} resulted in the highest grain yield e.g. 2239.0 and 2126.0 kg fed^{-1} in 1st and 2nd seasons, respectively.

Applying 80 kg N fed^{-1} resulted in lower grain and straw yields, where the reduction comprised 5.70 and 8.45%, respectively, in 1st season, and reached to 5.10 and 6.90% in 2nd season, respectively, as compared to 100 kg N fed^{-1} rate. These results are in harmony with those obtained by Lakhy (1988), Shaaban (2006), Ghanbari and Tavassoli (2013). Abolfazl (2013) and Abdelkhalek *et al.* (2015).

Likely to yield components, grain and straw yields exhibited similar trends under the adopted irrigation regimes, where the highest values were recorded under 40% SMD regime, which amounted to 2363.00 and 2721.85 kg fed^{-1} in 1st season and 2254.00 and 2598.94 kg fed^{-1} in 2nd one, respectively. Irrigating according to 60 or 80% ASMD resulted in reduced figures for wheat grain and straw yields, where the reduction reached to (8.25 and 11.11%) and (15.60 and 22.45%) in 1st season and by (8.70 and11.12%) and (15.18 and 22.16%) in 2nd season, respectively. These reductions may be referred to the undesired effect of moisture stress on reducing photosynthesis, cell division, stem elongation, leaf area, tillering and dry matter accumulation in plant organs. The obtained results are in the same line with those reported by Yordanov *et al.* (2003), Yousef and Ashry (2006) and Abdou *et al.* (2011).

Results in Table (5) show that wheat grain and straw yields were significantly affected by the interaction between N fertilization rates and irrigation regimes. Applying 100 kg N fed^{-1} and irrigation at 40 % ASMD gave the highest grain yields (2414.6 and 2322.82 kgfed^{-1}) and straw yields (2818.4 and 2700.96 kgfed^{-1}) in 1st and 2nd seasons, respectively

Crop - water relationships

1- Seasonal consumptive use (ET_C)

The results in Table (6) indicate that seasonal consumptive use or evapotranspiration (ET_C) of wheat crop, as a function of the applied N fertilization rates and irrigation regimes were 41.43 and 40.60 cm in 1st and 2nd seasons, respectively. The difference may be due to the variation in weather factors of the two seasons (Table 2). Applying 100 kg N fed^{-1} gave the highest values of ETc i.e. 42.22 and 41.28 cm in 1st and 2nd seasons, respectively. Decreasing N fertilizer rate to be 80 kg N fed^{-1} resulted in reduction in ETc amounted to 3.77 and 3.22 %, respectively, comparable with 100 kg N fed^{-1} rate in1st and 2nd seasons. These results may be referred to the reduction in vegetative growth and yield. In 2 – season field experiment with wheat, Abdelkhalek *et al.* (2015) reported that 90 kg Nfed^{-1} rate, as anhydrous ammonia increased CU (2.38 – 2.44 %), comparing with 75 kg N fed^{-1} one.

Regarding the effect of irrigation regimes, data in Table (6) reveal that irrigation wheat at 40 % ASMD (7 irrigation events were applied) produced the highest values of ET_C i.e. 43.72 and 42. 96 cm in1st and 2nd seasons, respectively. Furthermore, irrigation at 60 or 80% ASMD (6 and 5 irrigation events were applied, respectively) decreased ETc by 5.22 and 10.52 % and by 5.70 and 10.66% in the 1st and 2nd seasons, respectively, comparable to 40% ASMD. It obvious that increasing the available soil moisture in the root zone of wheat plants caused increase in ET_C. These results may be due to the high transpiration rates from plants and high evaporative demands from soil under high available soil moisture, conversely, under water stress, the transpiration from plants may decreased as a result of poor vegetative growth, also the evaporation decreased from dry soil surface. In general, crop evapotranspiration (ET), and more precisely, crop transpiration is positively and linearly related to grain yield in C3 and C4 plants; there-fore, water stress inevitably decreases yield (Ace-vedo *et al.* 2002). The present results are in accordance with those reported by Yousef and Ashry (2006) and Abdou *et al.* (2011). Furthermore, in 2- season experiment, Abdelkhalek *et al.* (2015) found that the highest CU for wheat crop (47.78 – 56.48 cm) was recorded with 5 irrigation events, and the value tended to reduce to be (41.91 – 48.72 cm) and (37.0 – 40.68 cm) with 4 and 3 irrigation events, respectively

Data in Table (6) indicate that applying 100 kg N fed^{-1} combined with irrigation at 40 % ASMD gave the highest values of ETc i.e., 44.56 and 43.87 cm in 1^{st} and 2^{nd} seasons, respectively. On the contrary, the lowest ET_C (38.38 and 38.05 cm) were recorded due to applying 80 kg N/fed as interacted with irrigation at 80 % ASMD, respectively, in 1^{st} and 2^{nd} seasons.

2- Daily ET_C ($mmday^{-1}$)

The results in Table (7) show that the daily ETc rates as function of the adopted treatments in both seasons were started with low values during November and decreased more during December, then increased again during January and February to reach its maximum during March. Thereafter, it decreased during April (plant harvesting). These results are attributable to that at the initial growth stages (germination and seedling), most of the water loss was due to evaporation from the bare soil. In addition, reduction in ET_C rate during December is due to the lower evaporative demands (air temperature, air humidity and solar radiation). Thereafter, as the plant cover and temperatures increased, evaporation and plant transpiration increased, and reached maximum values during heading and grain filling stages at March, whereas at maturity stage the plants tended to dryness and the ET_C rate decreased again during April (harvesting).

The results in Table (7) indicate that the values of daily ETc were slightly higher under 100 kg N fed^{-1} rate than 80 kg N fed^{-1}, and such results were true in 1^{st} and 2^{nd} seasons. As for the daily ETc peak during March and April, under 80 kg N fed^{-1} rate the values were lower by (4.7 and 0.3%) and (2.7 and 0.3%) than those under 100 kg N fed^{-1} rate, respectively, in 1^{st} and 2^{nd} seasons. Such results are attributable to vigorous plant growth and higher grain yield due to applying 100 kg N fed^{-1}.

Table (6): Effect of N fertilization rates and irrigation regimes and interaction on seasonal consumptive use of wheat crop (ET_C, cm) in 2013/14 and 2014/15 seasons

N rate (Liquid Ammonia)	2013/2014			Mean	2014/2015			Mean
	Soil Moisture Depletion				Soil Moisture Depletion			
	40%	60%	80%		40%	60%	80%	
80 kg N / fed	42.87	40.63	38.38	40.63	42.04	39.76	38.05	39.95
100 kg N /fed	44.56	42.24	39.86	42.22	43.87	41.25	38.71	41.28
Mean	43.72	41.44	39.12	41.43	42.96	40.51	38.38	40.62

Table 7: Effect of N fertilization rates and irrigation regimes and their interaction on daily water consumptive use (mmday^{-1}) in 2013/14 and 2014/15 seasons

N rate (Liquid Ammonia)	Soil moisture depletion	2013/2014						2014/2015					
		November	December	January	February	March	April	November	December	January	February	March	April
80 kg Nfed^{-1}	40%	1.58	1.29	1.72	2.18	4.54	3.61	1.46	1.26	1.47	2.26	4.58	3.57
	60%	1.58	1.20	1.56	2.02	4.28	3.54	1.46	1.18	1.40	2.13	4.22	3.46
	80%	1.58	1.15	1.45	1.81	4.03	3.41	1.46	1.09	1.32	1.98	4.11	3.32
Mean		1.58	1.21	1.58	2.00	4.28	3.52	1.46	1.18	1.40	2.12	4.30	3.45
100 kg Nfed^{-1}	40%	1.58	1.34	1.78	2.26	4.74	3.78	1.46	1.33	1.62	2.38	4.69	3.73
	60%	1.58	1.27	1.61	2.02	4.53	3.60	1.46	1.22	1.47	2.19	4.47	3.53
	80%	1.58	1.21	1.50	1.91	4.21	3.51	1.46	1.17	1.34	2.04	4.11	3.38
Mean		1.58	1.27	1.63	2.06	4.49	3.63	1.46	1.24	1.48	2.20	4.42	3.55
Irrigation regimes mean													
40%		1.58	1.32	1.75	2.22	4.64	3.70	1.46	1.30	1.55	2.32	4.64	3.65
60%		1.58	1.24	1.59	2.02	4.41	3.57	1.46	1.20	1.44	2.16	4.35	3.50
80%		1.58	1.18	1.48	1.86	4.12	3.46	1.46	1.13	1.32	2.01	4.11	3.35
Over All Mean		1.58	1.25	1.61	2.03	4.39	3.58	1.46	1.21	1.44	2.16	4.37	3.50

Irrigation at 40% of ASMD regime exhibited higher daily ETc values during entire growing season than 60 and 80% ASMD regimes in 1st and 2nd seasons. Such results could be attributable to luxury of available soil moisture, under 40% of ASMD regime, which subjected to transpiration through the crop canopy and evaporation from the soil surface as well. These results are in the same line of those reported by Yousef and Hanna (1998), Yousef and Ashry (2006), Abdou *et al.* (2011), and El-Akram and Emam (2014). It is worthy to mention that the peak of daily ETc values was recorded during March and April under the adopted irrigation regimes, and such result was true in 1st and 2nd seasons.

3- Reference evapotranspiration

Reference evapotranspiration rate (ET_0) in mmday^{-1} during the entire wheat growing seasons, i.e., 2013/14 and 2014/15, was estimated using the FAO Penman- Monteith method and the meteorological data of Fayoum Governorate listed in Table (3).The obtained data indicated that the ET_0 rate values were somewhat high during November and then decreased during December and January. Thereafter, the daily rates of ET_0 increased from February till April, in 1st and 2nd seasons. These results are attributed to the variation in climatic factors from month to another. Allen *et al.* (1998) reported that the reference ET values depend mainly on the evaporative power at particular area i.e., air temperature, solar radiation, air relative humidity and wind speed.

4- Crop coefficient (K_C)

The most known and used technique to estimate ET is the one based on the *Kc* approach (Allen *et al.,* 1998) where the *ETc* is calculated by using standard agro-meteorological variable and a crop-specific coefficient, the crop coefficient *Kc*, which should take into account the relationship between atmosphere, crop physiology and agricultural practices. The crop coefficient reflects the crop cover percentage and soil conditions on the ET_0 values. The K_C values were estimated from daily ET_C and daily ET_0 rates during the two growing seasons. The results in Table (8) reveal that the K_C values, as a function of the interaction between the applied N rates and irrigation regimes (as overall mean) were low during November and December, then increased during January (0.55 and 0.63) and February (0.59 and 0.68) as the vegetative growth increased to booting stage. The K_C values reached its maximum values (0.94 and 0.91) during March (heading – grain filling stage).

Table (8): Effect of N fertilization rates and irrigation regimes and their interaction on crop coefficient (K_C) of wheat in 2013/2014 and 2014/2015 seasons

N rate (Liquid Ammonia)	Soil moisture depletion	2013/2014						2014/2015					
		November	December	January	February	March	April	November	December	January	February	March	April
Reference ET_O, $mm\,d^{-1}$		3.4	2.5	2.9	3.5	4.8	6.1	3.2	2.2	2.3	3.2	4.8	6.5
80 kg Nfed^{-1}	40%	0.46	0.52	0.59	0.62	0.95	0.59	0.46	0.57	0.64	0.7111	0.95	0.55
	60%	0.46	0.48	0.54	0.58	0.89	0.58	0.46	0.54	0.61	0.67	0.88	0.53
	80%	0.46	0.46	0.50	0.52	0.84	0.56	0.46	0.50	0.57	0.62	0.86	0.51
Mean		0.46	0.49	0.54	0.57	0.89	0.58	0.46	0.54	0.61	0.67	0.90	0.53
100 kg Nfed^{-1}	40%	0.46	0.54	0.61	0.65	0.99	0.62	0.46	0.60	0.70	0.74	0.98	0.57
	60%	0.46	0.51	0.56	0.61	0.94	0.59	0.46	0.55	0.64	0.68	0.93	0.54
	80%	0.46	0.48	0.52	0.55	0.88	0.58	0.46	0.53	0.58	0.64	0.86	0.52
Mean		0.46	0.51	0.56	0.60	094	0.60	0.46	0.56	0.64	0.69	0.92	0.54
Irrigation regimes mean													
40%		0.46	0.53	0.60	0.64	0.97	0.61	0.46	0.59	0.67	0.73	0.97	0.56
60%		0.46	0.50	0.66	0.60	0.92	0.59	0.46	0.56	0.63	0.68	0.91	0.54
80%		0.46	0.47	0.51	0.54	0.86	0.57	0.46	0.52	0.58	0.63	0.86	0.52
Over All Mean		0.46	0.50	0.55	0.59	0.92	0.59	0.46	0.56	0.63	0.68	0.91	0.54

The K_C values decreased again during April (0.59 and 0.54), as plants started maturity and harvesting, in both seasons, respectively. These results may be attributed to the large diffusion resistance of bare soil during the initial growth stage (germination and seedling stages), which decreased gradually with increasing the crop cover until heading and grain filling stages. At maturity stage (April) the transpiration decreased, as a result of leaves and stem drying causing the low values of K_C during April. Data in Table (8) reveal that reducing N rate from 100 to 80 kg Nfed^{-1} decreased the K_C values during the entire growing seasons1st and 2nd seasons. Increasing the SMD from 40 to 60 or 80% exhibited trends similar to that under reducing N rate, where reduced K_C values were attained throughout the entire growing season in1st and 2nd seasons. Irrigation at 40% ASMD gave the highest K_C values during the entire growing season, whereas, the lowest ones were detected from irrigation at 80% ASMD in both seasons. The 2- season average of K_C values of wheat, as a function of different treatments were 0.46, 0.53, 0.59, 0.64, 0.92 and 0.57, for November, December, January, March and April, respectively. Such findings are in the same line of those reported by Yousef and Hanna (1998) Yousef and Ashry (2006) and Abdou *et al.* (2011).

5-Water use efficiency (WUE)

Water Use Efficiency is an efficiency term quantified as a ratio of product output (goods and services) over water input. The output could be biological goods such as crop grain, fodder….etc. Kang *et al.* (2002) stated that relationship between evapotranspiration (ET) and (GY) have been widely used for water-saving purpose in water deficit areas as a guideline for irrigation, it cannot explain the effects of timing of applications. Moreover, knowledge of crop-water requirements is crucial for water resources management and planning in order to improve water-use efficiency (Hamdy and Lacirignola, 1999). Results in Table (9) show that the WUE values, as a function of N fertilization rates and irrigation regimes, were 1.25 and 1.22 kg grain m^{-3} water consumed in 1st and 2nd seasons, respectively. Applying 100 kg N fed^{-1} resulted in the higher WUE values which comprised 1.26 and 1.23 kg grains m^{-3} water consumed in 1st and 2nd seasons, respectively. Reducing the N rate to be 80 kg N fed^{-1} exhibited lower WUE values reached to 2.38 and 2.44% less than those with100 kg N fed^{-1} in 1st and 2nd seasons, respectively

As for the tested irrigation regimes, data indicate that irrigating wheat crop as 40% of ASM was depleted gave the highest WUE values, which reached to 1.28 and 1.25 kg grains m^{-3} water consumed in1st and 2nd seasons, respectively. On the contrary, irrigation at 60 or 80 % ASMD regimes decreased the values of WUE in1st and 2nd seasons by 2.34 and 4.69 % in 1st season and 3.20 and 4.80% in 2nd season, respectively, comparable with 40 % ASMD regime. It could be noticed that WUE decreased as ASMD increased and such findings are in harmony with the results found by Yousef and Hanna (1998) and Yousef and Ashry (2006). On the contrary, Abdelkhalek *et al.* (2015) found that water productivity (WP) for wheat was decreased with increasing irrigation events. Such variation could be attributed to different experimentation, agronomic practices, prevailing climatic conditions ….etc.

The interaction data reveal that the highest WUE values (1.29 and 1.26 kg grains m^{-3} water consumed) were recorded with 100 kg Nfed^{-1} rate as interacted with 40 % ASMD regime in 1st and 2nd seasons, respectively, Table 9.

Table (9): Effect of N fertilization rates and irrigation regimes and their interaction on water use efficiency (WUE, kgm^{-3}) in 2013/2014 and 2014/2015 seasons

N rate (liquid ammonia)	2013/2014				2014/2015			
	40% (ASMD)	60% (ASMD)	80% (ASMD)	Mean	40% (ASMD)	60% (ASMD)	80% (ASMD)	Mean
80 kg Nfed^{-1}	1.26	1.23	1.19	1.23	1.24	1.20	1.18	1.20
100 kg Nfed^{-1}	1.29	1.26	1.24	1.26	1.26	1.22	1.20	1.23
Mean	1.28	1.25	1.22	1.25	1.25	1.21	1.19	1.22

Conclusion

Under the present experimentation, it is advisable to apply 100 kg N fed^{-1} (as liquid ammonia) and irrigating as 40% of the total available soil moisture was depleted in order accomplish higher grain and straw yields and reasonable water productivity values as well for wheat Giza 168 variety.

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استجابة القمح في الاراضي القديمة لمعدلات مختلفه من التسميد النتروجيني بالامونيا السائلة و ادارة الري تبعا لاستنزاف نسب مختلفة من الرطوبة الارضية الميسرة

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الملخص العربى

أقيمت تجربتان حقليتان بمزرعة محطة البحوث الزراعية بطامية – محافظة الفيوم – مصر . خلال موسمي ٢٠١٣/ ٢٠١٤ ، ٢٠١٤ / ٢٠١٥ لدراسة تأثير التسميد بمعدلات الامونيا السائلة بمعدل ٨٠ و ١٠٠ كجم ن /فدان (١ كجم من غازالامونيا يحتوى على ٨٢.٤ % نيتروجين) مع ثلاث معاملات للري هي الري عند استنزاف ٤٠ ، ٦٠ ، ٨٠% من الرطوبة الارضية الميسرة وذلك علي المحصول ومكوناته وبعض العلاقات المائية لمحصول القمح (جيزه ١٦٨) في تصميم القطع المنشقة مرة واحدة في أربعة مكررات وفيما يلي أهم النتائج المتحصل عليها:–

- كان تأثير معدلي التسميد النتروجيني معنويا مع أو بدون مستويات الري معنويا علي محصولي الحبوب و القش لنبات القمح و كذا مكونات المحصول تحت الدراسة مثل ارتفاع النبات، عدد السنابل /م٢ و وزن ١٠٠٠ حبة في موسمي الدراسة.
- أعطي معدل التسميد النتروجيني ١٠٠ كجم ن /فدان مع أو بدون الري بعد استنفاذ ٤٠% من الرطوبة الكلية الميسرة بقطاع التربة أعلي القيم للاستهلاك المائي. بينما كانت أقل قيمة للاستهلاك المائي مع اضافة ٨٠ كجم ن /فدان مع أو بدون الري بعد استنفاذ٨٠% من الرطوبة الكلية الميسرة ذلك في موسمي الدراسة. أعلي القيم من الاستهلاك المائي اليومي (مم/يوم) طوال موسم النمو سجلت مع المعدل الأعلي من التسميد النتروجيني ، و الري عند استنزاف ٤٠% من الرطوبة الأرضية أظهر نفس التأثير. أظهر معامل المحصول (Kc) سلوكا مشابة للاستهلاك المائي (الموسمي و اليومي) حيث سجلت القيم الأعلي مع المعدل الأعلي من التسميد النتروجيني و كذا مع الري عند استنزاف ٤٠% من الرطوبة الأرضية.
- كانت قيم كفاءة استخدام المياه (كدالة لمعاملات التسميد النتروجيني و مستويات الري تحت الدراسة) ١.٢٦ و ١.٢٣ كجم م⁻٣ مياة مستهلكة في ٢٠١٣/ ٢٠١٤ ، ٢٠١٤ / ٢٠١٥ ، علي التوالي . أدي اضافة التسميد النتروجيني بمعدل ١٠٠ كجم ن /فدان الي تحقيق قيم مرتفعة لكفاءة استخدام المياه (١.٢٥ و ١.٢٢ كجم م⁻٣) و ظهر نفس التأثير مع الري بعد استنفاذ ٤٠% من الرطوبة الكلية الميسرة بقطاع التربة (١.٢٨ و ١.٢٥ كجم م⁻٣)، علي التوالي ، في موسمي الدراسة. التفاعل بين معدل التسميد النتروجيني ١٠٠ كجم ن /فدان و الري بعد استنفاذ ٤٠% من الرطوبة الكلية الميسرة بقطاع التربة أعلي القيم لكفاءة استخدام المياه و كانت ١.٢٩ و ١.٢٦ كجم م⁻٣، علي التوالي ، في موسمي الدراسة.

بناءا علي النتائج المتحصل عليها يفضل اضافة ١٠٠ كجم ن /فدان (كأمونيا مسالة) مع اجراء الري عند استنزاف ٤٠% من الرطوبة الارضية الميسرة ذلك للوصول الي محصول عالي من الحبوب و القش للقمح جيزة ١٦٨ والحصول علي قيمة عالية من كفاءة استخدام المياه تحت ظروف منطقة طامية بالفيوم – مصر.

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