Efficient Use of N and Water for Maize (*Zea Mays* L.) Crop under Drip Irrigation System using ^{15}N Stable Isotope

M. A. Hekal[1], A. A. Abdel-Salam[2], S. M. Soliman[1], Y. G. M. Galal[1], M. Abd-El-Moniem[1], W. R. Zahra[2], and A. A. Moursy[1]

[1]*Soil and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Egypt.*

[2] *Soil and Water Department, Faculty of Agriculture, Moshtohor, Benha University, Egypt.*

Corresponding authors: Alyabsalam@yahoo.com & solimanreh@yahoo.com

ABSTRACT

A field experiment was carried out on Maize (*Zea Mays* L.) grown on a sand soil during 2017 season to assess implications of N rates and irrigation water on yield and water consumption. The design was a factorial randomized complete block involving two factors: Factor W: 3 irrigation treatments as % of an Etc of 6588 m^3 ha^{-1}, i.e. 100% (W_1), 80% (W_2) and 70% (W_3). Factor N: 3 N rates as % of a recommended 310 kg N ha^{-1},i.e.100% (N_1) ,80% (N_2) and 70% (N_3). Grain yields (Mg ha^{-1}) ranged from 2.80 (W_1N_3) to 4.48 (W_2N_2). Fertilizer N recovered in grains+stalks+leaves ranged from 5.4 % (W_2N_1) to 16.5% (W_2N_3). N use efficiency (kg grains kg^{-1} N) was 6.3 (W_1N_2) up to 18.6(W_3N_1). Water utilization efficiency (kg grains m^{-3} water) was 0.43 (W_1 N_3) to 0.84(W_3 N_3). High N and water use efficiency on sandy soils, must be by balanced combination water and N , and the general trend showed 5270 m^3 water and 248 kg N per hectare (representing 80% of officially recommended inputs of each)

Keywords: NUE, WUE, recovery of fertilizer N in maize, ^{15}N-Isotope dilution.

Introduction

The world demand for food is expected to increase by more than 70% by 2050 **(Tilman *et al.*, 2011).** In order to minimize the need for further expansion of cultivated lands, this increase needs to be partially achieved through increased crop productivity per unit area of arable lands **(Mueller *et al.*, 2012).** Much of the enhancement in crop productivity in the last half century has been achieved by increasing rates of agronomic inputs **(Borlaug, 2003).** However, to optimize the use of increasingly limited resources and avoid adverse environmental effects, yield increase needs to be through increasing the efficiency of the added inputs including fertilizers and irrigation water **(Tilman *et al.*, 2002).**

Maize (*Zea mays* L.) is one of most important food grain crops constituting a significant portion of total food grain production, particularly in many countries. **(Panda *et al.*, 2004).** World production of maize grains increased by more than two-folds in 2010 compared with the year 1961during which period new high-yielding cultivars were introduced along with improved agronomic practices **(Qian *et al.*, 2016)**.

Crop productivity depends mostly on heavy application of nutrients including N. Heavy application of chemical nutrients can cause environmental pollution **(Zahoor, *et al.*, 2014).** Improving nutrient use efficiency in agriculture calls for the development of sustainable nutrient management strategies, more efficient use of mineral fertilizers, and increased recovery of fertilizer nutrients. Nitrogen plays a vital role in cereal grain crop production , **(Jin *et al.*, 2012),** hence effective N fertilization management is very important in this concern **,** to increase grain yield **(Ma *et al.*, 2006)** and avoid N deficiency adverse effects on plant growth and yield **(Shahrokhnia and Sepaskhah, 2016).** In irrigated agriculture, it is important to maximize yield with minimum of water and increase the water use efficiency (WUE) of the crop. The crop water use is commonly measured as evapotranspiration (Et). It varies according to a number of factors, including climate, plant cultivar, and soil fertility. For effective management of irrigation, a comprehensive understanding of the actual crop evapotranspiration (Et) is necessary since it constitutes a major component of the hydrologic balance during the crop growing season. The two major yield-limiting inputs for most crops are water and nitrogen **(Rudnick *et al.*, 2016)**. According to **Morison et al (2008)** WUE can be applied to the water which is used in producing the economic crop produce (economic yield) , or the biological yield (which is represented by the above-ground biomass, or by the above-ground and below-ground 'roots" parts).

The current study aims at assessing maize response to the amount of applied water and fertilizer nitrogen and implications on yield and efficiency of fertilizer and water.

Materials and methods

A field experiment was conducted on maize plants (*Zea mays* cv. treble hybrid-329) grown on a sand soil of low fertility (Table 1) at the experimental farm of the Nuclear Research Center (NRC), of the Egyptian Atomic Energy Authority (EAEA), Abou-Zaabal, Egypt during 2017 summer season under drip irrigation system . The design of the experiment was a randomized complete block, factorial (2 factors) with 3 replicates**.** Factors are: (1) Irrigation (W), 3 treatments as % of an Et_c of 6588 m^3ha^{-1}, i.e. 100% (W_1), 80% (W_2) and 70% (W_3). (2) N: 3 N rates as % of a recommended 310 kg N ha^{-1},i.e.100% (N_1) ,80% (N_2) and 70% (N_3). Recommended Water and N being by **MALR (2016)**. The form of N was urea (460 g N kg^{-1}).The plot size was 10 m^2 Nitrogen was applied in five splits as follows; 30% two weeks after sowing (a.s.), 30% four weeks a.s. ; 20% six weeks a.s. and 20% eight weeks a.s. The irrigation system was drip, with each plot having its independent drip line. Seeds were sown on May 23rd 2017 and plants were harvested on September 10th (A 110-day season). A micro-plot of 1 m^2 was allocated in the middle of each plot for ^{15}N determination, and its N was in the form of ^{15}N urea with 2% ^{15}N atom excess (a.e.). All plots were given P and K as recommended by **MALR (2016):** 24 kg P ha^{-1} (as ordinary Ca-superphosphate 68 g P kg^{-1}) during soil preparations and 80 kg K ha^{-1} (as K-sulphate 400 g K kg^{-1}) in two equal splits (4 and 8 weeks after sowing). A foliar spray with Fe, Mn, Zn and Cu micronutrients was done with water solution containing 1300 mg of each (as chelated forms). Rate of spray was 1200 L ha^{-1} done twice, first four weeks a.s, second, four weeks of the first.

Table 1. Main properties of soil of the experimental field**:**

Particle size distribution (%)		**Soluble ions** (mmol$_c$ L^{-1})		**Total nutrients** (g kg^{-1})		**Available nutrients*** (mg kg^{-1})	
Sand	96.0	**Na^+**	6.8	**N**	0.5	**N**	0.30
Silt	4.0	**K^+**	3.6	**P**	2.0	**P**	0.04
Clay	0.0	**Ca^{2+}**	14.6	**K**	0.2	**K**	1.00
Texture*	Sand	**Mg^{2+}**	6.4	**Fe**	25.8	**Fe**	2.20
pH (1:2.5)	7.23	**$CO_3{}^{2-}$**	0.0	**Mn**	0.5	**Mn**	0.01
EC * (dS m^{-1})	3.14	**HCO^{3-}**	9.3	**Zn**	1.4	**Zn**	0.10
$CaCO_3$ (g kg^{-1})	0.0	**Cl^-**	8.5	**Cu**	1.4	**Cu**	0.20
OM (g kg^{-1})	0.3	**$SO_4{}^{2-}$**	13.6	***Texture: according to the international Texture Triangle (Moeys, 2016). Extractants for available nutrients: KCl (N); NH_4HCO_3-DTPA (P, K, Fe, Mn, Zn and Cu); EC of paste extract.**			

Soil was analyzed according to methods cited by **Carter and Gregorich (2008)** and plants were analyzed according to methods cited by **Estefan *et al.* (2013).** ^{15}N analysis was by emission spectrometer (Fischer NOI-6PC).). The portion of nitrogen derived from fertilizer (%Ndff) present in the relevant plant part(s) (%Ndff) was calculated as follows:

%Ndff = (^{15}N a.e. in plant ÷ ^{15}N a.e. in fertilizer) x 100

Efficiency parameters for applied N and water:

Efficiency parameters for applied N and irrigation water are those of (a) fertilizer N recovery (FNR), (b) fertilizer nitrogen use efficiency (NUE), and (c) irrigation water utilization efficiency (WUE). The FNR is the amount of fertilizer N in the crop as a % of the amount of applied N (**Bruulsema *et al.*, 2004**). According to **Hirel *et al.* (2011)** NUE is expressed as the yield obtained per unit of available N in the soil (supplied by the soil + N fertilizer). In the current study NUE is the yield obtained per unit of applied fertilizer N. The WUE is the yield of grains per cubic meter irrigation water (**Zhang *et al.*, 2005).**The equations for the 3 parameters are as follows:

1- FNR (% = {(%Ndff in plant X N uptake in plant) ÷ rate of applied N} X100.

Where: each of N uptake in plant N applied fertilizer N is in kg ha^{-1}.

2- NUE (weight of grains per kg of applied N) = grain yield "kg ha^{-1}" ÷applied N "kg ha^{-1}"

3-

$$\text{WUE}\ (\text{kg m}^{-3}) = \frac{\text{Yield (Y) (kg ha}^{-1})}{\text{Seasonal Crop Evapotranspiration (ETc) (m}^3\text{ha}^{-1})}$$

Results and discussion

Dry matter yield: (Table 2).

Stalks+leaves: The lowest stalks+leaves yield of 7.30 Mg ha_{-1} was obtained by N_3W_1 reflecting a low growth caused by a low nitrogen and high water application A low N addition combined by a high water application would lead to high loss by leaching of added N in such a course sand soil. The highest yield was given by N_3 W_2 surpassing the lowest by 74.7%. The indications are that such high plant growth is a manifestation of an efficient utilization of the low N rate where the irrigation was medium possibly with low loss by leaching. The second highest was given by N_1W_3 surpassing the lowest by 71.5% which shows an efficient use of a high N application with adequate water application sufficient for plant growth. The main effect of nitrogen application shows little non-significant differences between the three rates. Main effect of irrigation treatments shows greater positive effect of the medium irrigation treatment.

Grain yield: The pattern of grain yield was very much in line with that of the growth weight of stalks+leaves. The lowest grain yield of 2.80 Mg ha^{-1} was that of the N_3W_1 treatment as a result of a low growth caused by low N and high water application. The high irrigation water addition must have caused the low added N to suffer high loss by leaching, particularly and the soil is a sand in texture. The highest grain yield was given by N_2 W_2 surpassing the lowest by 52.5% ; a manifestation of efficient effect due to medium irrigation , apparently causing little N leaching loss combined with a medium N rate. The second highest was that of N_3 W_2 which surpassed the lowest by 46.8 %, reflecting an effective medium irrigation, despite a low N application. The main effect of nitrogen application shows no significant differences between the three rates and the main effect of irrigation shows greater positive effect of the medium and low irrigation (with no differences between them) over the high irrigation.

Table 2. Dry matter yield (Mg ha^{-1}) of maize plants as affected by nitrogen fertilization and water application rate.

Irrigation water (W) (% of ETc of 6588 m^{3}ha^{-1})	**Nitrogen fertilization (N) (% of the recommended 310 kg N ha^{-1})**							
	100 (N_1)	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**
	Stalks + leaves				**Grains**			
100 (W_1)	8.32	10.38	7.30	**8.67**	2.88	2.98	2.80	**2.89**
80 (W_2)	8.66	9.03	12.75	**10.15**	3.48	4.27	4.13	**3.96**
70 (W_3)	12.52	9.25	6.88	**9.55**	3.91	3.53	3.53	**3.66**
mean	**9.83**	**9.55**	**8.98**	**9.46**	**3.42**	**3.59**	**3.49**	**3.50**
LSD $_{0.05}$ W: 0.89 ; N: ns ; WN: 1.55					**LSD $_{0.05}$ W: 0.42 ; N: ns ; WN: ns**			

Notes: N_1, N_2 and N_3 are 310, 248 and 217 kg N ha^{-1} respectively; W_1, W_2 and W_3 are 6588, 5270 and 4612 m^3 ha^{-1} respectively.

N uptake: (Table 3)

N uptake in stalks +leaves: The two lowest N uptake of about 44 kg N ha^{-1} were obtained by either N_3W_3 or N_1W_2 indicating a low growth caused by a low N addition and high water application, or high N addition combined by a medium water application. The highest N uptake was obtained by the by N_1W_3 treatment surpassing the lowest by 86.6%.This indicates the high efficiency of the low N rate with high water application.

The main effect of nitrogen application shows a direct positive response to the high N rate which caused the highest N uptake in grains. The main effect of irrigation shows greatest positive effect of the low irrigation.

N uptake in grains: Results (Table 3) were rather comparable with those of the N uptake in the stalks+leaves. The two lowest N uptake of 32.2 kg N ha^{-1} were obtained by N_3W_1 indicating a low growth caused by a low N addition and high water application. The two highest N uptake were obtained by the N_2W_2 with 64.6 % over the lowest, and by N_1W_3 with 65.8% higher uptake over the lowest. This indicates a high efficiency of the medium N as well as medium water application or low N rate with high water application.

The main effect of nitrogen application shows a rather similar effect of the medium and high N, both surpassing the low N rate. The main effect of irrigation shows higher positive effects of the medium and low irrigations.

Fang *et al.*, (2006) studied maize growth grown on a silt clay soil under conditions of different water application and N addition. They recorded an increase in maize crop N uptake ranging from 281% to as high as 411% upon application of fertilizer N of 100 to 300 kgNha^{-1}. They noted high losses of fertilizer N in treatments with high irrigation than in low irrigation treatment.

Table 3. N uptake (kg ha^{-1}) by maize plants as affected by nitrogen fertilization and water application rate.

Irrigation water (W) (% of ETc of 6588 m^{3}ha^{-1})	**Nitrogen fertilization (N) (% of the recommended 310 kg N ha^{-1})**							
	100 (N_1)	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**
	Stalks + leaves				**Grains**			
100 (W_1)	59.9	56.7	44.5	**53.8**	39.3	35.5	32.2	**35.7**
80 (W_2)	44.1	48.4	64.8	**52.4**	38.1	53.0	40.5	**43.9**
70 (W_3)	82.1	60.6	43.8	**62.2**	53.4	45.7	41.7	**46.9**
mean	**62.0**	**55.3**	**51.0**	**56.1**	**43.6**	**44.7**	**38.2**	**42.2**
LSD $_{0.05}$ W: 3.09 ; N: 3.09 ; WN: 5.36					**LSD $_{0.05}$ W: 5.56 ; N: 5.56 ; WN: 9.63**			

See footnotes of Table 3

P uptake: (Table 4)

P uptake in stalks +leaves: The pattern of P uptake in stalks+leaves was very much in line with tat regarding weight of the stalks+leaves and to a marked extent with that of the N uptake. The lowest P uptake of 45.6 kg P ha^{-1} was obtained by N_3W_1 indicating the low growth caused by the low N and high water application. Presence of low applied N would be subject to loss by leaching due to the high water application in the sand soil. The highest P uptake was given by N_3 W_2 surpassing the lowest by 89.5%. Therefore, high uptake by the low N rate where irrigation was medium reflects efficiency of N and low loss by leaching.

P uptake in grains: Results were rather comparable with those of the N uptake in the stalks+leaves. The lowest P uptake of 19.6 kg P ha^{-1} was obtained by N_2W_1 reflecting the low grain yield (Table 2) caused by a high water application causing leaching losses of added fertilizer N. The highest P uptake was obtained by either the N_2W_2 or N_3W_3 with about 65 - 66% over the lowest indicating a balanced combination of medium N and medium water, or high N and water for the uptake of P.

The main effect of nitrogen application shows a high response to the medium or high N; both equally surpassing the low N rate. The main effect of irrigation shows higher positive effects of the medium and low irrigations. Such patterns are in harmony with the grain yield pattern.

Table 4 P uptake (kg ha^{-1}) by maize plants as affected by nitrogen fertilization and water application rate.

Irrigation water (W) (% of ETc of 6588 m^{3}ha^{-1})	**Nitrogen fertilization (N) (% of the recommended 310 kg N ha^{-1})**							
	100 (N_1)	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**
	Stalks + leaves				**Grains**			
100 (W_1)	53.1	69.9	45.6	**56.2**	32.9	19.6	21.0	**24.5**
80 (W_2)	55.4	77.6	86.4	**73.1**	30.4	34.2	28.6	**31.1**
70 (W_3)	78.8	51.3	63.46	**64.5**	31.7	26.0	31.0	**29.6**
mean	**62.4**	**66.3**	**65.1**	**64.6**	**31.7**	**26.6**	**26.87**	**28.4**
LSD $_{0.05}$ W: 8.28 ; N: ns ; WN: 14.35					**LSD $_{0.05}$ W: 3.34 ; N: 3.34 ; WN: 5.78**			

See footnotes of Table 3

K uptake (Table 5):

K uptake in stalks +leaves: Potassium uptake in stalks+leaves was rather similar to that regarding their weight and to a marked extent with that of the N and P uptake in them. The lowest K uptake of 100.8 kg K ha^{-1} was obtained by N_3W_3 reflecting the low growth caused by the low N and water application. The highest K uptake was given by N_1 W_3 surpassing the lowest by 105%, and exhibiting positive response to high N with no excessive irrigation to cause leaching loss of N.

K uptake in grains : Results show lowest K uptake of 20.6 kg K ha^{-1} was caused by N_3 W_1 reflecting low yield due to possible high loss of fertilizer N caused by high water application . The highest K uptake was obtained by N_3W_2 with an increase of 105% over the lowest indicating a balanced combination of low N and medium water. The main effect of nitrogen application shows a high response to the low or medium N; both equally surpassing the high N rate. The main effect of irrigation shows highest positive response to the medium irrigations. **Sitthaphanit *et al.* (2009)** obtained highest grain yield and NPK uptake with highest N applications.

Table 5. K uptake (kg ha^{-1}) by maize plants as affected by nitrogen fertilization and water application rate.

Irrigation water (W) (% of ETc of 6588 m^{3}ha^{-1})	**Nitrogen fertilization (N) (% of the recommended 310 kg N ha^{-1})**							
	100 (N_1)	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**
	Stalks + leaves				**Grains**			
100 (W_1)	132.2	177.2	107.9	**139.1**	29.5	25.3	20.6	**25.1**
80 (W_2)	128.6	145.9	197.0	**157.2**	30.2	38.4	42.3	**37.0**
70 (W_3)	206.5	150.7	100.8	**152.7**	31.3	35.5	34.5	**33.8**
mean	**155.8**	**157.9**	**135.3**	**149.7**	**30.3**	**33.1**	**32.5**	**32.0**
LSD $_{0.05}$ W: 8.3 ; N: 8.3 ; WN: 14.5					**LSD $_{0.05}$ W: 2.62 ; N: ns ; WN: 4.53**			

See footnotes of Table 3

Nitrogen derived from fertilizer (Ndff): (Table 6)**:**

Ndff in stalks+leaves: Ndff in stalks+leaves ranged from 5.77 kg N ha^{-1} by N_2W_2 to 14.96 kg ha^{-1} by N_2W_3 and 14.26 kg N ha^{-1} by N_3W_2 with the two latter treatments having no significant difference between them. This shows the importance of a balanced combination of N and water application.

Ndff in grains: Ndff in grains ranged from 16.84 kg N ha^{-1} by N_3W_1 reflecting a low N rate to 27.30 by N_2W_2 and 26.87kg N ha^{-1} by N_1W_3 with the two latter treatments having no significant difference between them. This shows the effect of medium to high N application. The importance of a balanced combination of N and water application is indicated in this response.

Table 6. Nitrogen derived from fertilizer "*Ndff* "(kg ha^{-1}) by maize crop as affected by nitrogen fertilization and water application rate*.

Irrigation water (W) (% of ETc of 6588 m^{3}ha^{-1})	**Nitrogen fertilization (N) (% of the recommended 310 kg N ha^{-1})**							
	100 (N_1)	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**
	Stalks + leaves				**Grains**			
100 (W_1)	9.24	10.33	10.38	**9.98**	22.68	18.32	16.84	**19.28**
80 (W_2)	6.96	5.77	14.26	**9.00**	19.64	27.30	21.06	**22.67**
70 (W_3)	12.88	14.96	11.90	**13.25**	26.87	23.98	19.80	**23.55**
mean	**9.70**	**10.35**	**12.18**	**10.74**	**23.07**	**23.20**	**19.23**	**21.83**

***1. See footnotes of Table 3; 2. Values are averages and no statistical analysis was done.**

Recovery of fertilizer N: (Table 7)

The recovery of applied fertilizer N in grains+stalks+leaves of the maize crop (Table 7) ranged from 5.63 % by the N_1W_2 treatment to as high as 16.51 % by the N_3W_2 treatment indicating a high recovery where the rate of N is low and the water application is medium. This shows a rather efficient recovery and low loss under such conditions. A low recovery 37% of fertilizer N in maize was reported by **Cassman *et al.* (2002** .The low recovery of fertilizer N obtained in the current study indicates possible loss by leaching of N especially and the soil was sand. **Islam et al (2014)** noted 45% loss of fertilizer N applied to a sandy soil under rice.

Table 7. Recovery of fertilizer N applied to maize as affected by N and water application (percentage of fertilizer N utilized by plant).

Irrigation water (W) (% of ETc of 6588 m^{3}ha^{-1})	**Nitrogen fertilization (N) (% of a recommended 310 kg N ha^{-1})**											
	100 (N_1)	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**
	Stalks + leaves				**grains**				**Grains+ Stalks + leaves**			
100 (W_1)	2.98	4.17	4.78	**3.94**	7.32	7.39	7.76	**7.49**	10.30	11.56	15.54	**12.47**
80 (W_2)	2.25	2.33	6.57	**3.72**	3.11	11.01	9.95	**4.69**	5.36	13.34	16.51	**11.74**
70 (W_3)	4.15	6.03	5.48	**5.22**	8.67	9.67	9.12	**9.15**	12.82	15.70	14.60	**14.37**
mean	**3.13**	**4.17**	**5.61**	**4.30**	**6.37**	**5.69**	**6.21**	**8.22**	**6.16**	**13.53**	**15.55**	**12.86**

See footnotes of Table 3.

Nitrogen use efficiency (NUE): (Table 8):

The lowest NUE (expressed as kg yield per kg N) was 23.54 for stalks+leaves, and 9.05 for grains (Table 8); both of which were given by the high water low nitrogen W_1N_3 treatment. This demonstrates a possible high loss of N under a high irrigation water and a low N presence.

The highest NUE was 59.60 for stalks+leaves, and 18.61 for grains; both were given by the low water high nitrogen W_3N_1 treatment. This particular treatment was among the highest 3 yields of the cop (see Table 2).

Assessment of NUE:

The high NUE indicates a high positive effect by low water application combined with the high N addition. These results assert the importance of irrigation and fertilization being the major yield-limiting factors in crop management **(Rudnick *et al.*, 2016)**.Increasing the efficiency of fertilizers and irrigation needs rationalization of their inputs **(Tilman *et al.*, 2002).**

Table 8: Nitrogen use efficiency "NUE "(kg produce kg^{-1} fertilizer N) by maize crop as affected by nitrogen fertilization and water application rate.

Irrigation water (W) (% of ETc (6588 m^3ha^{-1})	**Nitrogen fertilization (N) (% of a recommended 310 kg N ha^{-1})**							
	100 (N_1)	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**
	Stalks + leaves				**Grains**			
100 (W_1)	26.84	33.47	23.54	**27.01**	9.29	6.31	9.02	**9.31**
80 (W_2)	33.32	34.74	49.03	**36.13**	13.40	16.42	15.87	**15.23**
70 (W_3)	59.60	44.03	32.76	**39.32**	18.61	16.81	16.81	**17.41**
mean	**39.92**	**37.42**	**35.11**	**37.48**	**13.76**	**14.28**	**13.90**	**13.98**
LSD $_{0.05}$ W: 3.88	**; N: 3.88**	**; WN: 6.73**			**LSD $_{0.05}$ W: 1.81 ; N: ns ; WN: ns**			

Water utilization efficiency (WUE): (Table 9)

WUE by stalks+leaves: The lowest WUE in Stalks+leaves was 1.11 kg m^{-3} by N_3W_1 and the highest was 2.71 kg m^{-3} by N_1W_3 (Table 9).The second highest was 2.42 kg m^{-3} by N_3W_2. This indicates that it is the water application which mainly affects the water use efficiency. Applied N has an influence too. The high N application enhanced WUE. The low WUE is associated with the high amount of applied water while the high WUE is associated with the low amount of applied water.

WUE by grains: The pattern was rather similar to that of the WUE in Stalks+leaves. The lowest WUE in grains was 0.43 kg m^{-3} by N_3W_1 and the highest was 0.84 kg m^{-3} by N_1W_3.The second highest was 0.84 kg m^{-3} by N_2W_2. Therefore the response in terms of WUE is a function of water application in combination with N addition. Low WUE was associated with the high water application, while high WUE was associated with low water application. Thus the medium application of water combined with a medium nitrogen gave the highest WUE.

Assessment of WUE:

The pattern of response concerning WUE indicates an increase with a low irrigation water combined with a medium fertilizer N. This is useful and practical in water and fertilizer management, and may help in obtaining a sustainable yield of maize. **Gheysari *et al.* (2018)** studied WUE on silage maize using irrigation at different water depletion stages and different N rates. They found that a lowest WUE of 1.38 kg m^{-3} was by using a high water stress with no N addition, while a highest of 1.80 was by using irrigation with no water stress combined with a medium N of 200 kg ha^{-1}. **Zegada-Lizarazu *et al.* (2012**) noted that with low crop canopy, large fraction of applied water is lost causing low WUE. **Dercas and Liakatas (2007)** observed high WUE towards the end of the growing season of crops**. Morison et al. 2008)** mentioned that increasing *application of water* does not increase yield unless the crop transpiration is increased.

Final conclusion of the study:

Attaining the most effective results regarding N and water use efficiency for maize grown on dandy soils, there must be a balanced combination of irrigation water and N rate. Amounts which gave most efficient results in this study were 5270 m^3 water and 248 kg N per hectare (both representing 80% of the official **MALR** (2016) recommended rates of both inputs.

Table 9: Water utilization efficiency "WUE" (kg crop yield m^{-3} irrigation water) by maize as affected by N fertilization and water application rate.

Irrigation water (W) (% of ETc of 6588 m^3ha^{-1})	**N fertilization (N)** (% of the recommended (310 kg N ha^{-1}))							
	100 (N_1)	**80 (N_2)**	**70 (N_3)**	**mean**	**100 (N_1)**	**80 (N_2)**	**70 (N_3)**	**mean**
	Stalks + leaves				**Grains**			
100 (W_1)	1.26	1.58	1.11	**1.32**	0.44	0.45	0.43	**0.44**
80 (W_2)	1.64	1.71	2.42	**1.92**	0.66	0.81	0.78	**0.75**
70 (W_3)	2.71	2.01	1.49	**2.07**	0.84	0.77	0.77	**0.79**
mean	**1.87**	**1.77**	**1.67**	**1.77**	**0.65**	**0.68**	**0.66**	**0.66**
LSD $_{0.05}$ W: 0.18	**; N: ns**	**; WN: 0.31**			**LSD $_{0.05}$ W: 0.08 ; N:ns ; WN: ns**			

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كفاءة إستخدام النيتروجين والماء لمحصول الذرة الشامية تحت نظام الرى بالتنقيط باستخدام النظير المستقر ن ١٥

محمد أشرف هيكل[١]، على أحمد عبدالسلام[٢]، سليمان محمد سليمان[١]، يحيي جلال محمد جلال[١]، محمد عبدالمنعم[١]، وسام رشاد زهرة[٢] ، أحمد عبدالمنعم مرسى[١]
[١] قسم بحوث الأراضى والمياه، مركز البحوث النووية، هيئة الطاقة الذرية، أبوزعبل ١٣٧٥٩، مصر
[٢] قسم الأراضى، كلية الزراعة، مشتهر، جامعة بنها
Alyabsalam@yahoo.com & *solimanreh@yahoo.com*

الملخص العربى:

أجريت تجربة حقلية على نبات الذرة الشامية المنزرع فى أرض رملية خلال الموسم الزراعى صيف ٢٠١٧ لتقييم تأثير مستويات التسميد النيتروجينى ومياه الرى على المحصول وإستهلاك المياه. بتصميم قطاعات كاملة العشوائية randomized complete blocksعاملية factorialتشتمل عاملين الأول مياه الرى: كنسب مئوية من البخرنتح الموصى به (والذي = ٦٥٨٨ م^{3}/هكتار) ويضم ٣ مستويات : ١٠٠% (W_1)، ٨٠% (W_2)، ٧٠% (W_3). والثانى: تسميد نيتروجينى: كنسب مئوية من المعدل الموصى به (والذي = ٣١٠ كجم ن / هكتار) يضم ٣ مستويات: ١٠٠% (N_1)، ٨٠% (N_2)، ٧٠% (N_3). تراوح محصول الحبوب (مجج/هكتار) من ٢.٨٠ (W_1N_1) إلى ٤.٤٨ (W_2N_2). وتراحت الزيادة فى إسترجاع النيتروجين السمادى فى السيقان + الأوراق ما بين ٥.٤% (W_2N_1) إلى ١٦.٥% (W_2N_3). إزدادت كفاءة الإستخدام النيتروجينى (كجم حبوب /كجم نيتروجين سمادى) من ٦.٣ (W_1N_2) إلى ١٨.٦ (W_3N_1)، أما كفاءة إستخدام مياه الرى (كجم حبوب / م^{3} مياه رى) فزاد حتى تروحت من ٠.٤٣ (W_1N_3) إلى ٠.٨٤ (W_3N_3).وعموما فإن أفضل النتائج عمليا يمكن أن تكون ٥٢٧٠ م^{3} ماء ري مع ٢٤٨ كجم ن / هكتار(مجج هو مجاجرام megagram برمز Mg ودلالة مليون جرام أي طن متري : ١٠٠٠ كج)