Response of wheat to nitrogen fertilization under saline irrigation water conditions

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ADDITIONAL INDEX WORDS: calcareous soil, N-efficiency, N-fertilizer, water salinity and wheat cultivar.

ABSTRACT

Greenhouse experiments were conducted during two successive seasons to evaluate the effect of nitrogen fertilizer rates under irrigation with saline water on wheat (*Triticum aestivum* L.) productivity and soil salinity. Treatments included 5 N-fertilizer rates *i.e.* 0, 1.5, 3.0, 4.5 and 6.0 g N/ pot and 4 levels of salinity in irrigation water *i.e.* 0.60, 4.7, 9.4, 14.0 dS/m. Wheat variety Giza 168 was grown to maturity on calcareous soil. Soil properties were determined and wheat yield and yield components were recorded and statistically analyzed.

Salinity of irrigation water (EC_i) had a dominant effect on soil salinity, in which EC_e reached 6.55, 12.38 and 18.20 dS/m for EC_i of 4.7, 9.4, 14.0 dS/m, respectively. Sodium adsorption ration (SAR) increased from 5.13 to 12.77, 14.45 and 17.64 due to Na accumulation in soil. The results indicated that grain yield, biological yield, 100-grains weight, number of spikes, and plant height of wheat cultivar (Giza 168) were affected significantly ($p \leq 0.05$) due to nitrogen and salinity treatments. Averaging over salinity treatments, grain and biological yields increased significantly with increasing N-fertilizer rates up to 4.5 and 3.0 g N/ pot., respectively. Additional application of nitrogen was not consistent. On the other hand, grain and biological yields decreased significantly, as salinity increased. Biological yield was the most sensitive indicator to salinity, being reduced by 20.4, 40.6, and 56% at 4.7, 9.4, and 14.0 dS/m, respectively, compared with the control. While, grain weight expressed as 100-grains weight was the least sensitive character to EC_i, being decreased by 1.69, 5.91, and 9.92 % at the same salinity levels, respectively.

The results indicated that the nitrogen-use efficiency (NUE) reached the highest value at fertilizer rate of 3.0 g N/pot and the lowest EC_i. Doubling the nitrogen level from 1.5 to 3.0 g N/pot brought an increase in NUE values from 13.14 to 17.22, and then decreased to 10.21 by further nitrogen application up to 6.0 g N/pot. At low salinity, NUE was greater than at high salinity, suggesting that N aggravate salt damage at high salinity and reduced the apparent salt tolerance.

The present result may have important implications regarding to N fertilization, where the fertilization practices can be modified according to the prevailing soil salinity.

INTRODUCTION

In arid and semi-arid regions, due to the scarcity of fresh water resources, the use of low quality water including well and drainage waters become necessary. Since the saline water has been proposed as alternative irrigation source for crop production, attention should be drawn to its effects on yield potential and soil salinity status.

Wheat is one of the important cereal crops for human consumption, especially for the development countries. Much of this wheat grown on soils where salinity already exist or may develop. Considerable researches have been reported on the salt tolerance of wheat cultivars over the past years (Ayers *et al.*, 1952; Mass and Hoffman, 1977; Epstein, 1985; François *et al.*, 1986; Epstein and Rains, 1987). Excessive salt acts as an environmental stress, decreasing plant growth and yield potential. Salinity affects plant growth through water deficit, nutritional imbalance and/or ion toxicity (Balba and El-Etreiby, 1980; Epstein, 1985; Epstein and Rains, 1987). Trails in Egypt have shown that growth and grain yield of wheat was adversely affected by salinity of irrigation water (Barakat *et al.*, 1970; Fawzy *et al.*, 1977; Omar and Ghowail, 1991; Shalaby *et al.*, 1993; Gawish *et al.*, 1999).

Salinity-fertility relationships are of great economic importance and have been the subject of many greenhouse and field studies (Khalil *et al.*, 1967; Bernstein *et al.*, 1974; Barakat *et al.*1970; Fawzy *et al.*, 1977; Papadopoulos and Rendig, 1983). These studies were conducted to evaluate fertilization management as a means of alleviating growth inhibition due to salinity. Some of this published data indicate a positive effect of nitrogen and phosphorus application on crop salt tolerance (Lüken, 1962; Pavikovitch and Yoles, 1971; Barakat *et al.*1970; Fawzy *et al.*, 1977). In contradiction to the positive effect of increased levels of nutrient elements on crop salinity tolerance, other sources present data indicating a decrease in salinity tolerance (Khalil *et al.*, 1967; Peters, 1983). Other publications indicate no significant change in the relative salt tolerance of crops (Lunin and Gallatin, 1965; Pavikovitch and Yoles, 1971). It seems that the available information on crop salt tolerance response to the fertilizer application under saline conditions is not clear. The objective of this study is to provide further details on the N-fertilizer rates under irrigation with saline water on soil salinity and wheat productivity.

MATERIALS AND METHODS

The current work was carried out at Soil Salinity Lab., Alex., Agricultural Research Center, on a calcareous soil using wheat variety (Giza 168) grown to maturity during 2003 and 2004 seasons. The soil used is highly calcareous (32% $CaCO_3$) and has a sandy clay loam texture (22.5% clay, 32.5% silt, and 45% sand), 33.6% field capacity, 0.28% organic carbon, 0.5% total N, and $NaHCO_3$-extracted P (Olsen *et al.*, 1954) was 10 μg P/g soil as determined by phospho-molybdo-ascorbic acid method (Murphey and Riley, 1962).

Grains of wheat cultivar Giza 168 were planted on Nov. 25, 2003 and Nov. 20, 2004 in pots of 36 cm inside diameter and 29 cm height under free drainage condition. Three weeks latter, thinning was conducted to maintain five seedlings/pot until maturity. A uniform application of P-fertilizer as calcium superphosphate (15.5% P_2O_5) was added at planting at the rate of 200 kg/fed. Treatments include five N rates (0, 1.5, 3.0, 4.5, and 6.0 g N/pot) and four salinity levels of irrigation water (0.6, 4.7, 9.4, and 14.0 dS/m). Nitrogen fertilizer in the form of ammonium nitrate (33.5% N) was splitted into three equal doses applied at seedling, tillering, and heading stage. Potassium fertilizer as K_2S0_4 (48% K_2O) was applied before the third irrigation at the rate of 100 kg/fed. All other cultural practices were applied as recommended. Saline water was constructed by dissolving $CaCl_2$ and NaCl (1:2 weight ratio) in tap water to give the appropriate salt concentration. The treatments were arranged in a randomized complete block design and replicated three times. Three weeks after planting, the pots were irrigated with the saline irrigation water treatments. The quantity and frequency of irrigation was used according to plant need and the weather conditions in addition to 20-30% leaching fraction to avoid any risk from salt accumulation.

At harvest, wheat grain and biological yields (g/pot), number of spikes/pot, 100-grains weight (g) and plant height (cm) were recorded. A mathematical approach was used to calculate the slope of polynomial regression equations to describe the effect of N fertilization and salinity of irrigation water on wheat production. Nitrogen–use efficiency, in terms of yield produced per applied nitrogen unit was estimated. The results obtained were statistically analyzed using the pooled data over the two seasons by using personal computer according to Dagnelie (1975).

Soil analysis:

Soil samples were collected before cultivation and after harvest for analysis. Soil paste extracts were conducted and analyzed for pH, EC and soluble cations and anions according to Richards (1954). Other chemical and physical analyses were performed as mentioned by Black (1965). Some chemical properties of the soil surface (0-20cm) are given in Table 1.

Table 1. Main characteristics of the used soil.

EC_e	pH	$CaCO_3$	Soluble cations				Soluble anions		
			Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}
dS/m		%	meq/L						
1.80	8.29	32.10	4.35	3.32	10.05	0.40	2.72	9.37	6.05

RESULTS AND DISCUSSION

Soil salinity:

The results indicate that the salt content of the irrigation water expressed in EC_i had a dominant effect on soil salinity of the paste extract (EC_e) as illustrated in Table 2 and Fig.1. Linear regression equation was developed to describe the pattern of relation between EC_i and EC_e:

$$Y = 0.934 + 1.226\,X \qquad 0.60 \leq X \leq 14.0 \qquad R^2 = 0.99 \qquad (1)$$

where Y is EC_e and X is EC_i, all expressed in dS/m.

The positive value of the slope of equation 1 indicates to the magnitude of salt stress of irrigation water on soil salinity. The soil salinity (EC_e) reached 1.80, 6.55, 12.38 and 18.20 dS/m for irrigation water of 0.6, 4.7, 9.4, and 14.0 dS/m, respectively. The use of saline water, EC_i = 9.4 with SAR of 14.45 in irrigated agriculture cannot be sustained without periodic application of chemical amendments to offset this degradation and to enhance optimum plant growth and soil productivity. The data agree with other observations obtained by El Haddad *et al.* (1993), El Etreiby (2002) and El Ashter (2004).

Table2. Average composition of saturated soil extract at the end of the experiment.

EC_i	EC_e	pH	Soluble cations				Soluble anions			
			Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}	SAR
dS/m	dS/m		----------meq/L----------							
0.6	1.80	8.29	4.35	3.32	10.05	0.40	2.72	9.37	6.05	5.13
4.7	6.55	8.49	12.27	10.73	43.31	0.50	2.77	50.70	12.57	12.77
9.4	12.38	8.40	28.61	23.45	73.71	0.67	3.07	98.66	24.83	14.45
14.0	18.20	8.00	40.81	36.06	109.33	1.26	3.40	154.4	30.69	17.64

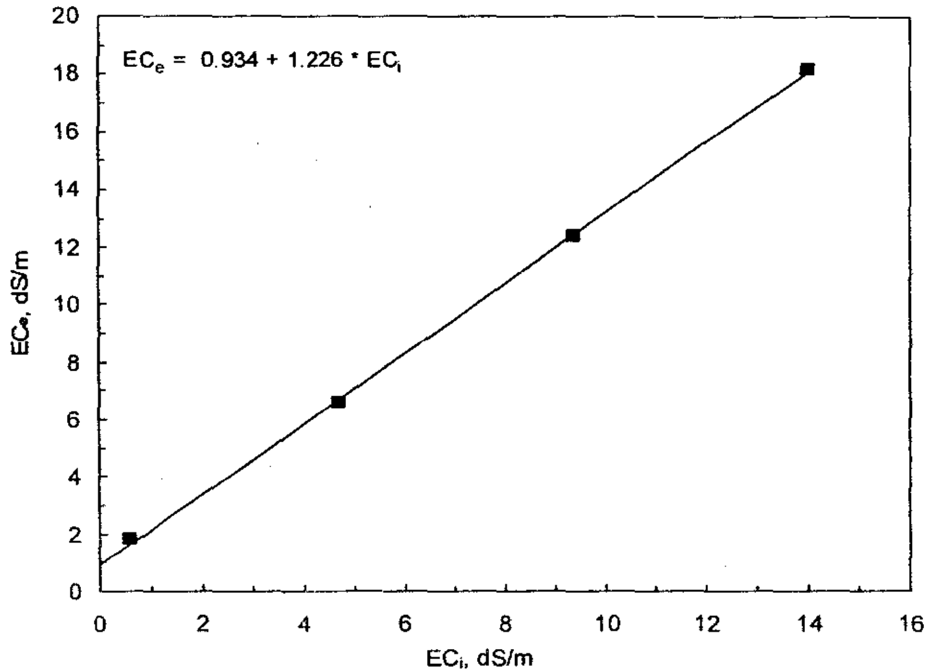

Fig. (1). Soil salinity of the saturated past extract (EC_e) as a function of salinity of irrigation water (EC_i).

Nitrogen effects:

Grain and biological yields, 100-grains weight, number of spikes, and plant height of wheat cultivar (Giza 168) were affected significantly ($p \leq 0.05$) with nitrogen and salinity treatments (Table 3). Regardless of salinity treatments, grain and biological yields were increased significantly with increasing N-fertilizer rates up to 4.5 and 3.0 g N/pot., respectively. Further application of nitrogen was not consistent. Grain yield was increased over the control treatment by 67.71, 166.45, 209.16, and 206.16 % for 1.5, 3.0, 4.5, and 6.0 g N/ pot, respectively. The corresponding values for biological yield were 115.7, 234.1, 257.4, and 264%, respectively. It seems that the vegetative part of wheat had a greater response to N fertilization than that found for grain yield. Number of spikes/pot showed the same trend as grain yield, while 100-grains weight and plant height were not responded significantly to N fertilization rate more than 3.0 g N/ pot.

Table 3. Means of different characters of wheat (Giza 168 cultivar) as affected by N- fertilizer rate and saline water levels.

Factors	Characters				
	Grain yield g/pot	Biological yield g/pot	100-grains weight g	No. of spikes /pot	Plant height cm
Fertilizer, g N/pot					
0.0	21.40	37.66	3.92	7.00	62.83
1.5	35.89	81.25	4.45	13.75	67.58
3.0	57.02	125.83	4.62	19.25	72.83
4.5	66.16	134.58	4.82	23.83	73.50
6.0	65.52	137.08	4.85	23.58	74.83
L.S.D 0.05	6.02	16.31	0.23	2.62	4.19
Salinity, dS/m					
0.6	64.50	146.00	4.74	20.07	79.00
4.7	57.21	116.13	4.66	20.13	73.87
9.4	44.34	86.67	4.46	16.07	66.60
14.0	30.74	64.33	4.27	13.67	61.80
L.S.D 0.05	7.38	34.58	0.25	2.34	3.75

Salinity effects:

Disregarding fertilizer rate, increasing salinity of irrigation water up to 14.0 dS/m reduced significantly ($p \leq 0.05$) all the studied traits (Table 3). Biological yield was the most sensitive character to salinity among the other yield and yield components, being reduced by 20.4, 40.6, and 56% at 4.7, 9.4, and 14.0 dS/m, respectively, compared with the control (0.6 dS/m). On the other hand, grains weight expressed as 100-grains weight was the least sensitive character to EC_i being decreased by 1.69, 5.91, and 9.92% at the same salinity levels, respectively. It was found that plant heights taken at harvest time showed that plants grown at the highest salinity (14 dS/m) were 21.8 % shorter than those of the control treatment. The results clearly indicate that reduction of wheat grain yield resulted from increasing salinity was attributed mainly to a reduction in number of spikes/pot and 100-grain weight. These results are consistent with those obtained by earlier investigators (François *et al.*, 1986; Abdel-Halim *et al.*, 1988; François *et al.*, 1988; El Etreiby 2002).

Nitrogen x salinity interaction effects:

Nitrogen x salinity interaction showed a significant effect on grain yield and was not consistent for the other characters under study. As shown in Fig. 2, at each salinity level up to 4.7 dS/m , increasing N-application rate from 0 to 6.0 g N/pot, increased grain yield of wheat, while application of 6.0 g N/pot to salinity level of 9.4 or 14.0 dS/m was not reliable. The differences in grain yield, due to salinity, were relatively small for non-fertilized treatments and increased with N-application rates. The response of grain yield as a function of N application at each salinity level was expressed by polynomial regression equations:

$Y = 25.817 + 20.484\,X - 1.687\,X^2$	at control	$R^2 = 0.964$	(2)
$Y = 18.772 + 18.586\,X - 1.283\,X^2$	at EC_i 4.7 dS/m	$R^2 = 0.954$	(3)
$Y = 17.525 + 13.200\,X - 0.947\,X^2$	at EC_i 9.4 dS/m	$R^2 = 0.928$	(4)
$Y = 15.724 + 11.523\,X - 1.448\,X^2$	at EC_i 14.0 dS/m	$R^2 = 0.990$	(5)

where Y is grain yield (g/pot) and X is the N-application rate in g N/pot. It was more clear from the above equations that, when salinity is a limiting factor, at 9.4 and 14.0 dS/m, increasing N application will be relatively ineffective compared to lowest salinity level.

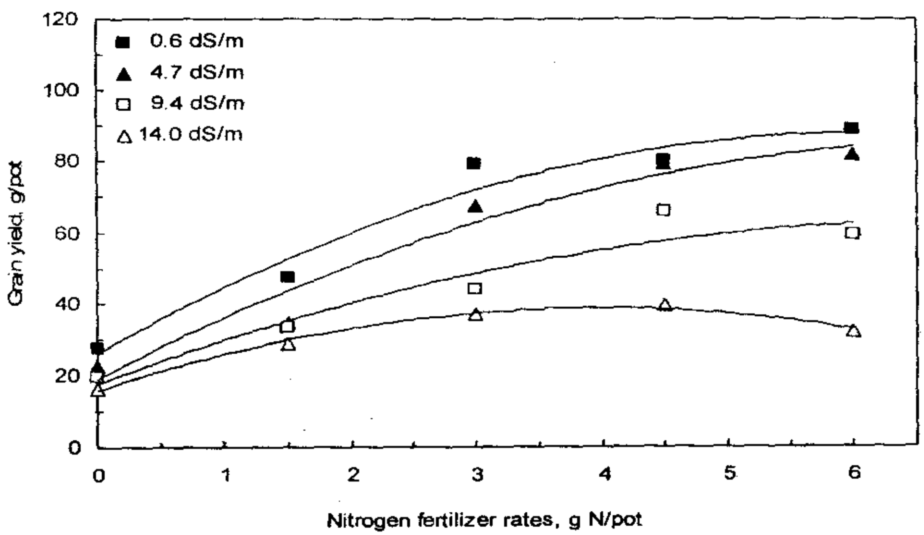

Fig. (2). Response of wheat grain yield to N fertilization under different salinity levels.

On the other hand, Fig. 3 demonstrates the relationship between grain yield and salinity levels under different N-rates. The results show that the response curves for 0 and 1.5 g N/ pot treatments were essentially parallel, while at 4.5 and 6.0 g N/ pot treatments, the curves tended to converge suggesting that N aggravate salt damage at high salinity. The best fitting model was polynomial equation to describe the pattern of relationship between EC_i and grain yield at each level of nitrogen:

$Y = 28.042 - 1.226X + 0.028X^2$	at control	$R^2 = 0.996$	(6)
$Y = 47.929 - 2.832X + 0.108X^2$	at N=1.5 g /pot	$R^2 = 0.936$	(7)
$Y = 83.279 - 4.546X + 0.083X^2$	at N=3.0 g/pot	$R^2 = 0.971$	(8)
$Y = 79.309 + 1.436X - 0.306X^2$	at N=4.5 g/pot	$R^2 = 0.998$	(9)
$Y = 89.901 - 0.942X - 0.230X^2$	at N=6.0 g/pot	$R^2 = 0.998$	(10)

where Y is grain yield (g/pot) and X is EC_i in dS/m. On the other hand, application of high level of N (i.e., 4.5 and 6.0 g N/pot) increased the absolute grain yield, but at the same time decreased the apparent salt tolerance as shown in Fig. 4. Other similar cases were mentioned, by Mass and Hoffman (1977), who concluded that crops grown under low fertility levels may show exceptionally high relative salt tolerance and application of N fertilizer would aggravate the apparent salt tolerance.

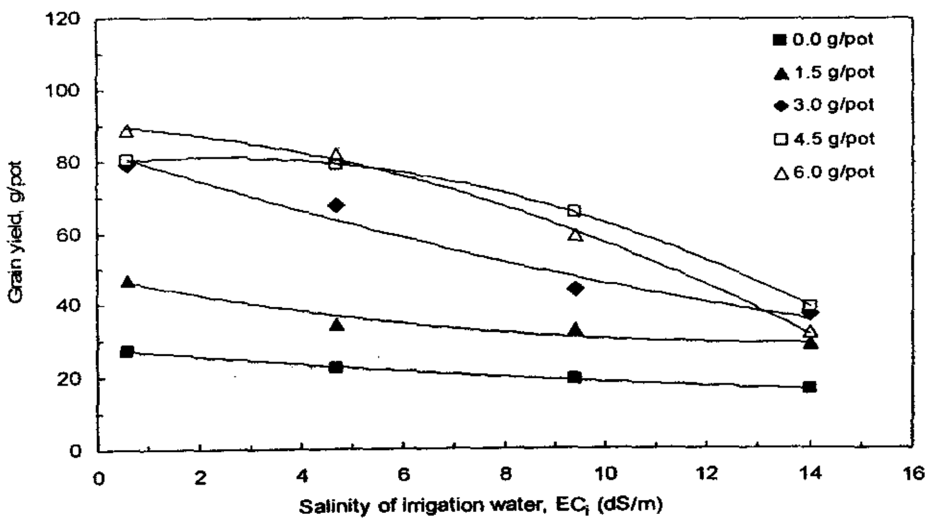

Fig. (3). Response of wheat grain yield to salinity levels under different N-fertilizer rates.

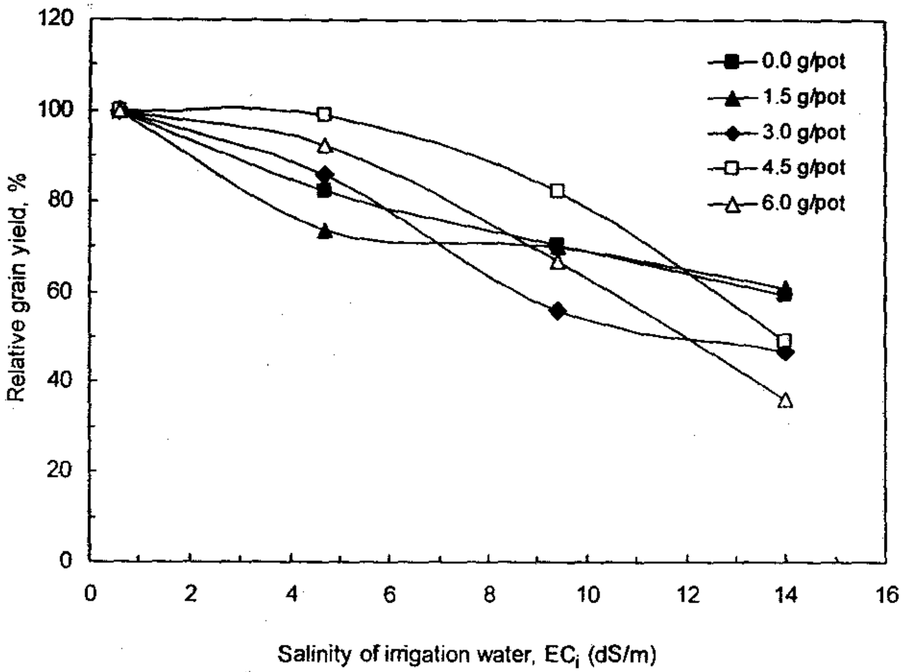

Fig. (4). Relative grain yield of wheat as affected by salinity levels under different N- fertilizer rates.

Nitrogen–use efficiency:

Nitrogen-use efficiency, in terms of yield produced per applied nitrogen unit under salinity stress was estimated by $(Y_i–Y_c)/N_r$.
Where, Y_i is yield obtained from N treatments, Y_c is yield obtained from control and N_r is applied nitrogen rate.

Figure 5 indicates that N-fertilizer rate and salinity levels had a dominant effect on nitrogen-use efficiency. At the lowest salinity level (0.6 dS/m) nitrogen-use efficiency reached to a maximum value (17.22) following addition of 3.0 g N/pot, thereafter it was decreased by higher nitrogen rates. The same pattern of grain yield-nitrogen response was obtained at salinity levels of 4.7 and 9.4 dS/m. At each nitrogen level, nitrogen-use efficiency was higher as long as salinity was lower. The results are in consistence with those obtained by Moll *et al.* (1982), who found that all studied hybrids of corn were less efficient in use of the high level of supply. The present result may have important implications regarding to N fertilization, where the fertilization practices can be modified according to the prevailing soil salinity.

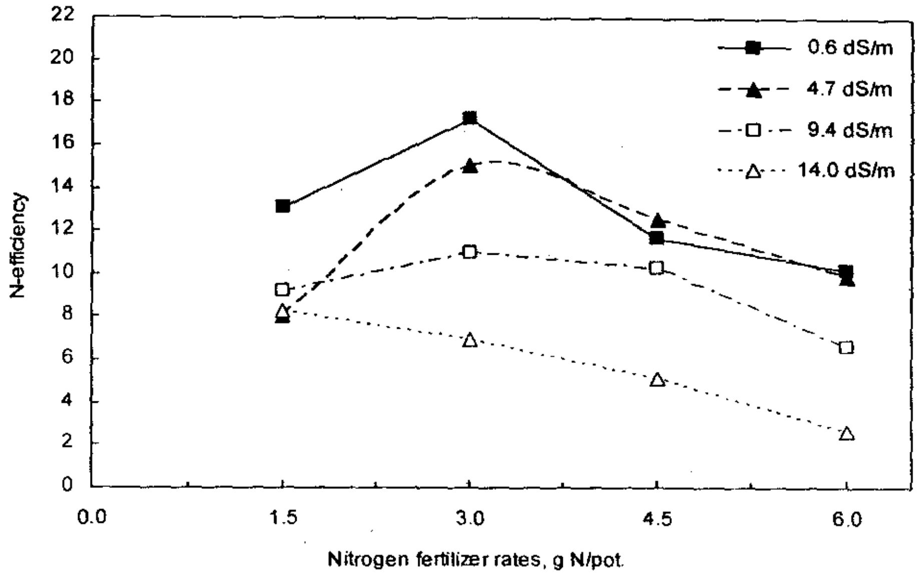

Fig. (5). Nitrogen-use efficiency (NUE) as affected by nitrogen application rate and salinity levels.

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الملخص العربى

أستجابة القمح للتسميد النتروجينى تحت ظروف الرى بمياه ملحية

أحمد عبد الرازق أبوشال ، عبد الفتاح الأشطر

قسم بحوث الأراضي الملحية والقلوية – معهد بحوث الأراضى والمياه والبيئة

أجري هذا البحث فى صوبه زجاجية فى موسمين متتالين لتقييم معدلات التسميد النتروجينى مع الرى بمياه ملحية على إنتاجية القمح وملوحة الأرض (جيرية). واشتملت الدراسة على خمس معدلات من النتروجين: بدون إضافة ، ١,٥ ، ٣,٠ ، ٤,٥ ، ٦,٠جم نيتروجين /إصيص وأربع تركيزات من مياه البحر المخففة لها قيم توصيل كهربائى (EC_i) : ٠,٦ (مياه الصنبور) ، ٤,٧ ، ٩,٤ ، ١٤ ديسى

سيمنز/م. تم زراعة الصنف جيزة ١٦٨ حتى النضج وخصص لكل معاملة ثلاث مكررات. قدرت خواص الأرض و سجلت بيانات محصول الحبوب ومكوناته وعولجت النتائج بالطرق الإحصائية.

أوضحت النتائج أن قيم التوصيل الكهربي (EC_e) للأرض الجيرية زادت من ١,٨٠ (معاملة المقارنة) إلى ٦,٥٥ ، ١٢,٣٨ ، ١٨,٢٠ ديسى سيمنز/م ، كما زادت قيم SAR من ٥,١٣ إلى ١٢,٧٧ ، ١٤,٤٥ ، ١٧,٦٤ مع استخدام المعاملات المختلفة لمياه الرى (EC_i): ٠,٦ ، ٤,٧ ، ٩,٤ ، ١٤ ديسى سيمنز/م على التوالى.

بينت النتائج أن كلا من معاملات التسميد النتروجينى ومعاملات الملوحة كان لهم تأثيرا معنويا على محصول الحبوب ، المحصول البيولوجى ، وزن ١٠٠حبه ، عدد السنابل وارتفاع النبات. حيث زاد محصول الحبوب معنويا مع زيادة معدلات التسميد النتروجينى حتى معدل ٤,٥ جم نتروجين/ إصيص بينما أزداد المحصول البيولوجى حتى معدل ٣ جم نتروجين/ إصيص، ولم تكن الإضافات التالية من النتروجين معنوية فى كليهما. من ناحية أخرى ، انخفض كلا من محصول الحبوب والمحصول البيولوجى معنويا عند زيادة ملوحة مياه الرى. كان المحصول البيولوجى هو القياس الأكثر حساسية للملوحة حيث انخفض بنسب ٢٠,٤ ، ٤٠,٦ ، ٥٦% بالنسبة إلى معاملة المقارنة عند الرى بمستويات ملوحة ٤,٧ ، ٩,٤ ، ١٤ ديسى سيمنز/م على التوالى. بينما وزن الحبوب معبرا عنة بوزن ١٠٠ حبة كان القياس الأقل حساسية للملوحة حيث انخفض بنسب ١,٦٩ ، ٥,٩١ ، ٩,٩٢% عند الرى بنفس قيم مستويات الملوحة السابقة على التوالى.

وصلت كفاءة النتروجين المستعمل (NUE) لأعلى قيمة عند معدل تسميد ٣ جم نتروجين/ إصيص ومستوى ملوحة ٤,٧ ديسى سيمنز/م. عند زيادة معدل التسميد النتروجينى من ١,٥ إلى ٣ جم نتروجين/ إصيص زادت كفاءة النتروجين المستعمل من ١٣,١٤ إلى ١٧,٢٢% ثم انخفض إلى ١٠,٢١ عند استخدام معدل ٦جم نتروجين/ إصيص. أيضا كانت كفاءة النتروجين المستعمل أعلى عند مستويات الملوحة المنخفضة عنها عند مستويات الملوحة المرتفعة ، مما يدل على أن النتروجين يفاقم التأثير الضار للملوحة العالية ويقلل التحمل للملوحة. مما سبق فالدراسة الحالية لها دلالـه هامة بخصوص التسميد النتروجينى حيث تبين أن الممارسات التسميدية يمكن أن تتغير طبقا لملوحة الأرض السائدة.