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Response of Two Wheat Cultivars to Supplemental Nitrogen under Different Salinity Stress

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Abstract

Effects of supplemental nitrogen (N), as either farmyard manure (FYM) or urea, on response of two wheat (*Triticum aestivum*) cultivars (a salt sensitive 'Sakha 69' and a salt tolerant 'Sakha 93') were investigated in a green house experiment under various salinity levels (control, 6, 9, or 12 dS m^{-1}). Grain and straw yields of both cultivars decreased with an increase in salinity levels. Supplamental N application, using FYM or urea, mitigated the adverse effects of salinity only at the low salinity level (6 dS m^{-1}). This effect was greater in a salt tolerant cultivar (Sakha 93) than that in a salt sensitive cultivar (Sakha 69). At the moderate and high salinity (9 and 12 dS m^{-1}) levels the supplemental N had no beneficial effects in mitigating the salinity stress of both cultivars. The mean grain yields, across all salinity levels and cultivars, of the plants received FYM and urea were greater by 11, and 8%, respectively, as compared to that of the plants received no supplemental N. The corresponding values for straw were 12 and 7%. The concentrations of N, P and K in the grain and straw significantly decreased with increasing salinity levels. Concentrations of Na, Cl, and Ca in the grain and straw were greater in salt sensitive cultivar than those in a salt tolerant cultivar. Concentrations of these elements significantly increased with an increase in salinity levels. This study demonstrated that supplemental N, as either FYM or as Urea, can mitigate negative effects of mild salinity stress, and that this beneficial effect was greater in a salt tolerant cultivar as compared to that in a salt sensitive cultivar.

Keywords: abiotic stress, salinity, nitrogen sources, farm yard manure, mineral nutrition, *Triticum aestivum*

1. Introduction

Soil salinity is a serious problem in Egypt with upto 33% of the cultivated land impacted by high salinity due to low precipitation (< 25 mm annual rainfall) and irrigation with saline water (El-Hendawy et al., 2005). Salinity is the major environmental factor limiting plant growth and productivity worldwide (Munns, 2002). The negative effects of salinity on plant growth may be associated to an increase in the osmotic potential of the soil solution that reduces plant available water, or increase in concentrations of certain ions that inhibits plant metabolism (Onani, 2005).

Wheat is the most important cereal crop in Egypt, however, domestic wheat production supplies only 40% of the demand. Increasing wheat production is a priority to maintain food security. Therefore, it is important to develop crop management alternatives to overcome the salinity stress, hance increase total wheat production.

Nitrogen (N) plays a vital nutritional and physiological role in plants. Plants can take up N as an anion (nitrate) or as cation (ammonium). Plant tolerance to high salt content in the growth medium may increase, decrease or remain unchanged with increasing rates of nutrients applications depending on the specific experimental conditions, including the level of salt stress (Irshad et al., 2002a). Therefore, the objective of this study was to evaluate the effects of different sources of supplemental N on the response of wheat cultivars to different levels of salinity.

2. Materials and Methods

Two wheat cultivars i.e. Sakha 93 (salt tolerant) and Sakha 69 (salt sensitive) were used. A pot experiment was conducted in a green house at the National Research Centre, Cairo, Egypt, using plastic pots of 30 cm height and 25 cm diameter with 8 kg clay loam soil (0-30 cm depth) per pot. Some physical and chemical properties of the soil used in the study are shown in Table 1.

Table 1. Some physical and chemical properties of the soil used in this experiment

Characteristics	Value
Particle size distribution	
Coarse sand (mg/g)	70.0
Fine sand (mg/g)	200.0
Silt (mg/g)	350.0
Clay (mg/g)	380.0
Textural class	Clay loam
pH (1:2.5)	7.4
ECe (dS m^{-1})	1.3
Soluble cations (meq/L)	
Calcium	4.9
Magnesium	3.5
Potassium	0.7
Sodium	4.7
Soluble anions (meq/L)	
Carbonate	0.0
Bicarbonate	8.1
Chloride	3.2
Sulphate	2.6
Organic matter (%)	1.8
Calcium Carbonate (%)	3.6
Available Nutrients	
Nitrogen (ppm)	76
phosphorus (ppm)	18
potassium (ppm)	160

Table 2. Some properties of the farmyard manure used in the study

pH (1:10)	EC (dS m^{-1}) (1:10)	OM (%)	OC (%)	C/N ratio	Concentrations of (%)			
					N	P	K	Ca
7.64	7.50	35.5	20.64	21.5	0.96	0.29	2.15	0.32

All pots received uniform rates of fertilizer application prior to sowing, i.e. 0.6, 0.8, and 0.4 g of urea, single superphosphate and potassium sulphate, respectively, which is equivalent to 180, 240, and 120 kg/ha N, P, and K, respectively. Ten seeds were planted per pot. N topdressing was done three weeks after sowing using urea at N rate equivalent to 180 kg/ha.

Treatments included three salinity levels of 6, 9, and 12 dS m^{-1} using 1:1 ratio of NaCl:$CaCl_2$. A control treatment with no added salinity was also included with an initial soil salinity of 1.3 dS m^{-1}. Subtreatments were supplemental N sources: i.e. (i) farmyard manure 81.63 g /pot before sowing (equivalent to 48 Mg/ha, at 0.96% N in FYM, total N application was 460 kg/ha); (ii) urea at 1.8 g/pot equivalent to 540 kg/ha applied in three doses, i.e. before sowing, and 3 and 5 weeks after sowing; (iii) no supplemental N, as a control. The experiment was conducted with four replications. Some properties of the farmyard manure used in this study are shown in Table 2.

Plants were harvested 150 days after sowing (maturity stage, late November 2011). Dry weights of straw and grain per pot were recorded. Concentrations of N, P, K, Na, Ca, and Cl in the straw and grian were analyzed following the procedure reported by Cottenie et al. (1982). Effects of treatments on plant response parameters were evaluated by analysis of variance (ANOVA) and mean separation test using SAS program (SAS, 1991).

3. Results and Discussion

3.1 Grain and Straw Yield

The grain and straw yields were significantly influenced by the cultivar, salinity levels as well as supplemental N treatments (Table 3). Only salinity X supplemental N interaction effect was significant on the grain yield. Straw yield, however, was significantly influenced by all two way interactions. The mean grain and straw yields, across both salinity and supplemental N treatments, were significantly greater for salt tolerant Sakha 93 cultivar as compared to those for a salt sensitive Sakha 69 cultivar (Table 4). The grain yields were 13.03, 12.31, 8.86, and 7.58 g/pot, while the straw yields were 14.95, 11.46, 9.52, and 7.41 g/pot for control and salinity levels of 6, 9 and 12 dS m^{-1}, respectively.

Table 3. Analysis of variance (ANOVA) for single factor and interaction effects of cultivars (C), salinity levels (S), and supplemental nitrogen (N) treatments on response parameters of wheat cultivars

Sources	Grain yield	Straw Yield	Na		Cl		Ca		N		P		K	
			Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Significance of F test														
C	0.26*	0.19*	0.007*	0.025*	0.014*	0.049*	NS	0.039*	0.024*	0.024*	0.015*	0.012*	0.016*	0.057*
S	0.37*	0.27*	0.01*	0.036*	0.02*	0.069*	0.020*	0.054*	0.068*	0.035*	0.020*	0.018*	0.023*	0.080*
N	0.32*	0.23*	NS	0.03*	0.016*	0.059*	NS	0.047*	0.059*	0.030*	NS	0.016*	NS	0.070*
CxS	NS	0.38*	0.016*	0.051*	0.027*	0.098*	0.03*	0.077*	0.096*	0.049*	0.028*	NS	NS	NS
SxN	0.63*	0.47*	NS	NS	NS	NS	NS	NS	NS	0.060*	0.015*	NS	NS	NS
CxN	NS	0.33*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CxSxN	NS	NS	NS	NS	NS	NS	NS	Ns	NS	NS	NS	NS	NS	NS

Note. NS = non significant; * = significant at P ≥ 95%.

Table 4. Effects of cultivars, salinity levels, and supplemental nitrogen sources on grain and straw yields of wheat cultivars and concentrations of selected mineral elements in grain and straw

Variables	Grain yield	Straw Yield	Na		Cl		Ca		N		P		K	
			Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
	-------g/pot-------		----------Percent in DM (w/w)----------											
<u>Cultivars:</u>														
Sakha 93[#]	11.27a	11.86a	0.06b	0.69b	0.15b	2.45b	0.36a	2.24b	2.44b	0.55a	0.36a	0.21a	0.52a	2.90a
Sakha 69[$]	9.63b	9.81b	0.09a	0.91a	0.18a	2.94a	0.35a	2.32a	2.47a	0.47b	0.34b	0.19b	0.48b	2.83b
<u>Salinity:</u>														
Control[&]	13.03a	14.95a	0.04c	0.25d	0.12d	1.45d	0.28d	2.11d	2.89a	0.77a	0.42a	0.22b	0.56a	3.47a
6	12.31b	11.46b	0.05c	0.61c	0.15c	2.39c	0.33c	2.19c	2.45b	0.53b	0.39b	0.24a	0.54a	2.91b
9	8.86c	9.52c	0.08b	0.98b	0.18b	3.13b	0.38b	2.36b	2.34c	0.40c	0.31c	0.19b	0.47b	2.62c
12	7.58d	7.41d	0.12a	1.36a	0.21a	3.82a	0.43a	2.47a	2.16d	0.35d	0.28d	0.16c	0.44c	2.46d
<u>N sources:</u>														
Control[@]	9.76c	10.14c	0.072a	0.76c	0.18a	2.61c	0.35a	2.37a	2.41b	0.45c	0.34a	0.18c	0.50a	2.79c
FYM	10.99a	11.49a	0.075a	0.84a	0.16ab	2.87a	0.36a	2.15c	2.50a	0.56a	0.35a	0.23a	0.52a	2.94a
Urea	10.59b	10.87b	0.073a	0.80b	0.15b	2.71b	0.36a	2.32b	2.45ab	0.52b	0.34a	0.20b	0.50a	2.87b

Note. *Means followed by similar letters are not significantly different (P > 95%), by each column and by each variable; [#]Salt tolerant; [$]Salt sensitive; [&]No added salinity; [@]No Supplemental N.

Supplamental N, regardless of sources, increased the grain and straw yields of both cultivars only under no salinity or at the low salinity (6 dS m^{-1}) treatments (Figures 1 and 2). At the high salinity treatments (9 and 12 dS m^{-1}) supplemental N failed to provide any benificial effects of mitigating the negative effects of salinity. The magnitude of beneficial effects of supplemental N as compared to no supplemental N was greater in Sakha 93 than that in Sakha 69 cultivar. This is somewhat expected in line with the physiological difference among the cultivars, i.e. mitigation of negative effects of salinity by an external treatment is often greater for a salinity tolerant cultivar as compared to that for a sensitive cultivar. The grain yield increases were 11 and 8% For FYM and urea as compared to that for control, respectively, while the corresponding values for straw were 12 and 7%. The results are consistent with the findings of Sushila and Giri (2000), Uyanoz et al. (2006), and Bayu et al. (2006).

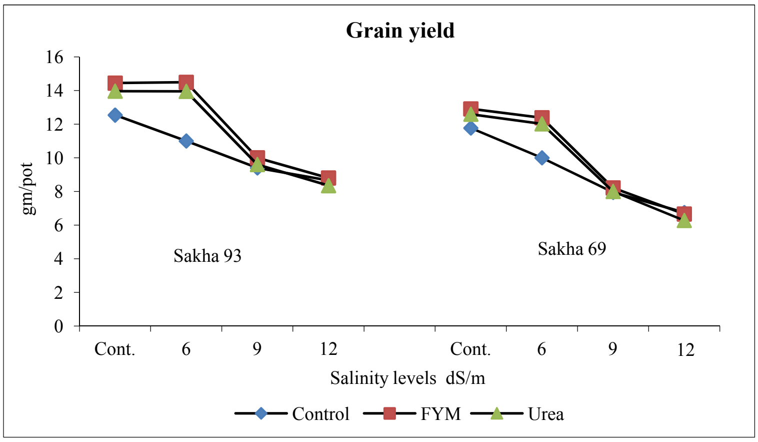

Figure 1. Effects of salinity levels and supplemental N treatments on grain yield of a salt tolerant (Sakha 93) and a salt sensitive (Sakha 69) wheat cultivars

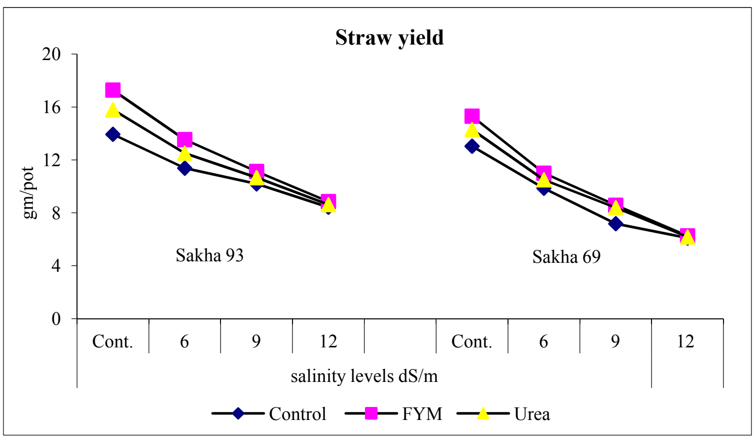

Figure 2. Effects of salinity levels and supplemental N treatments on straw yield of a salt tolerant (Sakha 93) and a salt sensitive (Sakha 69) wheat cultivars

The adverse effects of salinity were greater for Sakha 69 as compared to that for Sakha 93. The grain yield reductions at the highest salinity level as compared to that with the control were 47.2% and 36.9% for Sakha 69 and Sakha 93, respectively. The corresponding values for straw were 56.5% and 44.9%. Ahmed et al. (2005) reported 14% decrease in grain yield of salt tolerant wheat cultivar (LU 26S) with an increase in salinity level to 12.7 dS m^{-1} as compared to 52% decrease for a salt sensitive cultivar (SRC 3).

3.2 Concentrations of Na, Cl and Macronutrients in Grain and Straw

Concentrations of Na and Cl increased significantly in the grain and straw with an increase in salinity levels (Tables 3 and 4). The magnitude of increase was greater in the straw as compared to that in grain. This trend is in accordance with the finding of Ahmedi et al. (2009). Concentrations of Na and Cl, in both grain and straw were significantly greater in the salt sensitive Sakha 69 cultivar as compared to those in a tolerant cultivar Sakha 93 (Table 4). These results are in agreement with the findings of Schachtman and Munns (1992).

Increasing soil salinity levels significantly increased Ca concentrations in both grain and straw. Calcium concentrations in the grain were 0.28, 0.33, 0.38, and 0.43% with salinity treatments of control, 6, 9, and 12 dS m^{-1}, respectively, while the corresponding values in the straw were 2.11, 2.19, 2.36 and 2.47%. This could be attributable to increased Ca availability with increasing salinity levels that was achieved by using 1:1 ratio of NaCl:$CaCl_2$. Furthermore, the reduction in both grain and straw yields with an increase in salinity levels also contribute to an increase in Ca concentrations on dry matter basis. Ca concentration in the straw was significantly greater in Sakha 69 (2.32%) as compared to that in Sakha 93 (2.24%). On the other hand, there was no significant difference between the two cultivars with respect to Ca concentrations in the grain.

Concentrations of N, P, K in both grain and straw decreased with an increase in salinity levels from control to 12 dS m^{-1} (Table 4). The adverse effects of salinity on N concentration could be attributed to the presence of high amount of chloride which could decrease N uptake as reported by Saneoka, et al. (1999) and Uyanoz et al. (2006). Supplamental N application as FYM or Urea increased N concentration in the grain and straw. Concentrations of macronutrients in the grain and straw were greater in Sakha 93 as compared to those in Sakha 69, except the concentration of N in grain. The trend was reverse for the latter. El-Agroudi et al. (2005) reported greater N uptake by a salt tolerant wheat cultivar as compared to that by a salt sensitive cultivar.

Nitrogen concentration in the straw decreased significantly with increasing salinity levels, across both supplemental N and no supplemental N treatments. El-shafie et al. (2003) reported a significant increase in N uptake by wheat plants grown under saline condition with addition of FYM. Navarro et al. (2001) stated that phosphorus availability is reduced in saline soils because phosphate concentration in the soil solution is controlled by Ca-P interaction.

The concentrations of K in the grain and straw decreased with an increase in salinity levels (Table 4). This could be attributable to an antagonism for K uptake by an increase in Na and Ca availabity in the soil, since salinity increase was achieved by using NaCl and $CaCl_2$. Such antagonism for cation uptake was reported by Mostafa (2001) and Ahmedi et al. (2009).

Supplamental N application had no significant effects on K concentrations in the grain, but significantly increased K concentrations in the straw as compared to that of the plants with no supplemental N. This positive effect was greater with application of FYM than that with application of urea. These results are consistent with the findings of Hassan and Mostafa (2002), El-Shafie et al. (2003), and Irshad et al. (2002b).

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