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Response of Wheat to Nitrogen Fertilizer at Reclaimed High Terrace Salt-affected Soils in Sudan

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ABSTRACT

A Field trial was carried out for three consecutive seasons (2004-2005, 2005-2006 & 2006-2007) to study the influence of nitrogen (N) fertilizer application on the growth and yield of wheat crop on reclaimed high terrace soils (Aridisols). Two wheat varieties used were Wadielneel and Debeira. The experiment consisted of 4 N levels consisting of 0, 43 (half of recommended dose for wheat), 86 (recommended) and 129 (1.5 times of recommended) kg N/ha. The N fertilizer source was urea. Phosphors in form of triple superphosphate was applied to all treatments at sowing at a rate of 43 kg P_2O_5/ha. The straw and grain yields were significantly increased with the increase in dose of N fertilizer in both varieties. Variety Debeira gave higher grain yield under the same N level compared to Wadielneel. Application of 86 kg N/ha and 129 kg N/ha resulted in grain yield of 3.87 and 4.82 t/ha, respectively for Debeira and 3.64 and 4.03 t/ha, respectively for Wadielneel. From the results so it could be recommended that 129 kg N/ha level is required for Debeira and Wadielneel variety on reclaimed high terrace salt-affected soils.

Key Words: Wheat; Nitrogen; Growth; Grain yield; Salt-affected soils

INTRODUCTION

Salinity is one of the major environmental stresses that drastically affect crop productivity (Epstein *et al.*, 1980), especially in arid and semi-arid regions (Speer *et al.*, 1994). In certain situations, it is very difficult and expensive to reclaim salt-affected soils for improvement in crop production. Wheat is a major food crop in most of the countries, where salinity is a threat and is moderately tolerant to salinity (Qureshi & Barrett-Lenard, 1998).

Optimal rates of fertilizer application to salt-affected soils partially alleviate the adverse effects of salinity on photosynthesis and photosynthesis-related parameters and yield and yield components through mitigating the nutrient demands of salt-stressed plants (Papadopoulos & Rendig, 1983; Sultana *et al*., 2001). The proper use of N fertilizer in all soil is important, but particularly so in saline soils, where N may minmize the adverse effects of salinity on plant growth and yield (Shen *et al.,* 1994; Soliman *et al.,* 1994; Albassam, 2001; Flores *et al.*, 2001; Abdelgadir *et al*., 2005) depending on plant species, salinity level, or environmental conditions (Grattan & Grieve, 1999).

Soil salinity is one of the main abiotic constraints that affect wheat production in the high terrace soils of northern part of Sudan. High terrace soils consist of a number of soil series with a range of limitations for sustainable agriculture. The main limiting factors are very poor soil fertility, sodicity, salinity and some physical limitations. High terrace soils generally have low N content. Although the importance of N fertilization in increasing wheat production has been well documented, it is difficult to determine the quantities to apply under reclaimed saline conditions. This is due to lack of information on N uptake and its distribution among plant parts under these conditions. The objective of this study was to study the influence of N fertilizer application on wheat yield in reclaimed high terrace soils of Northern State in Sudan.

MATERIALS AND METHODS

The experiment was carried out on a high terrace soils (Aridisols) at Dongola Research Station Farm, Dongola, Sudan (19^o 10' N & 30^o 29' E) during 2004-2005, 2005-2006 and 2006-2007 cropping seasons. Although the research farm soils were salt affected and no soil reclamation program was undertaken, continued use of the farm fields for experimentation has resulted into improved crop performance and decrease in salinity levels over time. Currently, these farm soils are considered as reclaimed or partly reclaimed high terrace soils.

The experiment was conducted on these soils. Sirelkhatim (2001) reported that the initial average EC was

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7.5 dS/m for the upper depth (30 cm) and 8.5 dS/m for the lower two depths (30-60 & 60-90 cm). Mean SAR values were 14.2, 14.7 and 15.4 for the three respective depths. Some selected physio-chemical characteristics of the reclaimed soil are represented in Table I.

The experiment consisted of 4 N levels consisting of 0, 43 (half of recommended dose for wheat), 86 (recommended), and 129 (1.5 times of recommended) kg N/ha. The N fertilizer source was urea. Triple superphosphate at a rate of 43 kg P_2O_5/ha was applied to all treatments at sowing. Nitrogen fertilizer was applied in two equal doses with the first dose applied with second irrigation and the second one with fourth irrigation. Two wheat varieties used were Wadielneel and Debeira. The experiment was replicated four times in a split-plot design with main plots allotted to N treatments and subplots to varieties. The plot size was 4 x 7 m with a net harvested area of 3 x 6 m. With a seed rate of 125 kg/ha, sowing was done in late November. Data were recorded for grain yield, biomass, 1000 seed weight, number of head/m^2 and plant height. The data were analyzed using MSTAT statistical package. Combined analysis of variance was carried out for all the data.

RESULTS AND DISCUSSION

Crop growth and yield: Table II data show that plant height for both varieties i.e. Debeira and Wadielneel significantly increased with increasing application of N fertilizer; this effect was consistent for the three seasons. The amount of N application also significantly affected plant height. Interaction was non-significant among the both varieties and the four N doses. Plant height increased with increasing N level from the control level to 129 kg/ha. Maximum plant height (87.1 cm) was recorded when N level was 129 kg/ha, while minimum plant height (65.0 cm) was recorded in the control. The plant height for the both varieties averaged over doses of N showed that Debeira had maximum plant height (81.3 cm), while Wadielneel had the minimum plant height (77.2 cm). The interaction between N and the both varieties was found to be non-significant. However maximum plant height (89.3 cm) was recorded for Debeira when N level was 129 kg/ha, while Debeira also had minimum plant height (66.2 cm) with 0 kg/ha N was applied. These results are supported by the findings of Saleem (1987) and Khan *et al*. (2000) who reported that increasing the level of nitrogen increased the plant height.

Thousand seed weight is an important yield parameter. Table III data showed that there were no significant differences in the 1000-seed weight of the both varieties. The N levels significantly affected 1000-seed weight. Interaction among the both varieties and the four N levels was also found not significant. There were no significant differences among N treatments in the 1000-seed weight and also under the same N level for both varieties. Kernel differs in shape, color, texture and numerous other

Table I: Some physio-chemical properties of the soil in the Dongola research station farm

Parameters	Depth (cm)		
	0-25	25-50	50-75
pH (paste)	7.85	7.83	7.93
EC (dS/m)	1.06	1.34	1.98
CaCO3 %	3.90	3.29	3.18
Na (meq/L)	8.3	9.7	13.6
Ca + Mg (meq/L)	14.2	15.7	17.5
SAR	3.1	3.9	5.0
ESP (%)	3	4	6
Sand (%)	26	30	36
Silt (%)	20	21	16
Clay (%)	54	49	48

characteristics depending on the variety. Spiertz and Allen (1978) showed that increase in grain yield from applied nitrogen was not due to an increase in seed weight, but to the kernel number per unit area.

Nitrogen application resulted in significant increase in biomass yield for both varieties with the increase in nutrient application rates (from 0 to 43, 86 & 129 kg N/ha) in all the seasons (Table IV). However the effect of N application was significantly different for yield of both varieties. Variety Debeira gave higher biomass yield compared to Wadielneel. Nitrogen application at 86 kg/ha and 129 kg/ha resulted in average biomass yield of 7.46 and 8.23 t/ha, respectively for Debeira and 5.94 and 6.97 t/ha for Wadielneel. The difference of this interaction clearly showed the differential response of plants to N fertilizer under reclaimed high terrace soils. Latiri-Souki *et al.* (1998) reported that irrigation and N fertilizer application increased dry matter production and grain yield. They suggested that the increase might be due to increased leaf area index (LAI), green spikes area and an increase in green period of the leaves, which resulted in increased capture of radiation energy and consequently more dry matter production. Spiertz and Hole (1984) attributed increase in grain yield from N application to an increase in the number of kernels per unit area.

The response of wheat grain yield to different levels of N fertilizer during three seasons is presented in Table V. Variety Debeira produced higher grain yield than Wadielneel at the same N level. Grain yield progressively increased as rate of N was increased from the control level (no N application) to N application at 129 kg/ha. Grain yields were significantly higher in the 129 kg N/ha treatment than other treatments for both varieties. Application of 86 and 129 kg N/ha resulted in grain yield of 3.87 and 4.82 t/ha, respectively for Debeira and 3.64 and 4.03 t/ha, respectively for Wadielneel.

Economic evaluation: Partial budget analysis revealed profitability of using 129 kg N/ha compared with 86 kg N/ha as shown by the marginal rates of return (MRR) for both varieties (510 & 146% for Debeira & Wadielneel, respectively). Profitability expressed as MRR was greater for Debeira due to the higher increase in productivity than Wadielneel leading to increased yield difference between 129 and 86 kg N/ha for variety Debeira (Table VI).

Table II: Effect of nitrogen fertilizer application to a reclaimed salt-affected terrace soil on plant height (cm) of wheat (average of three cropping seasons)

Cultivars	Nitrogen level (kg/ha)				Wv main effect
	0	43	86	129	
			2004-2005		
Debeira	71.8±1.33	83.3±1.20	87.3±1.44	91.8±1.75	83.5
Wadielneel	63.0±1.13	71.5±1.51	80.5±1.15	80.5±1.73	73.9
N main effect	67.4	77.4	83.9	86.2	78.7
Significance:	N: *** Wv: *** N x Wv: NS				
	N= 1.23 , Wv = 1.17, NxWv = 2.33,		CV% = 5.93		
			2005-2006		
Debeira	48.5±1.91	70.5±2.19	77.0±2.26	76.0±2.16	68.0
Wadielneel	51.5±2.51	69.5±1.57	77.0±2.51	79.3±2.58	69.3
N main effect	50	70	77	77.6	68.7
Significance:	N: ***, v: NS, NxWv: NS				
	N= 1.65 , Wv = 1.23, NxWv = 2.46,		CV%= 7.18		
			2006-2007		
Debeira	78.3±1.91	93.3±1.90	98.1±2.24	100±2.22	92.4
Wadielneel	76.8±2.09	87.8±2.27	94±1.81	95±1.34	88.4
N main effect	77.5	90.5	98.1	97.5	90.4
Significance:	N: NS, Wv: NS, NxWv: NS				
	N= 0.54 , Wv = 0.38, NxWv = 0.77		CV%= 13.16		
			Combined (2004-2005 to 2006-2007)		
Debeira	66.2	82.3	87.4	89.3	81.3
Wadielneel	63.8	76.3	83.8	84.9	77.2
N main effect	65.0	79.3	85.6	87.1	
Significance:	N: ***, Wv: ***, NxWv: NS				
	N= 0.90 , Wv = 0.64, NxWv = 1.28,		CV%= 5.59		

Table III: Effect of nitrogen fertilizer application to a reclaimed salt-affected terrace soil on 1000 seed weight (g) of wheat (average of three cropping seasons)

Cultivars	Nitrogen level (kg/ha)				Wv main effect
	0	43	86	129	
			2004-2005		
Debeira	33.3±0.96	38.5±0.72	39.8±0.58	38.5±2.74	37.5
Wadielneel	34.5±1.05	36.5±0.70	37.3±0.33	37±0.42	36.3
N main effect	33.9	37.5	38.5	37.8	36.9
Significance:	N: * Wv: NS NxWv: NS				
	N= 1.0 Wv = 0.45, NxWv = 0.89,		CV%= 4.85		
			2005-2006		
Debeira	27.5±1.91	33±1.10	33.8±0.47	34.8±0.38	32.3
Wadielneel	29±0.68	32.8±1.12	34.8±0.39	36±0.45	33.1
N main effect	28.3	32.9	34.3	35.4	32.7
Significance:	N: ***, Wv: NS, NxWv: NS				
	N= 0.76 , Wv = 0.42, NxWv = 0.83,		CV%=5.09		
			2006-2007		
Debeira	39.3±1.0	45±2.01	40.3±1.0	37±1.0	40.4
Wadielneel	39.3±1.0	39.8±1.0	40.8±1.0	37.8±1.0	39.4
N main effect	39.3	42.4	40.5	37.4	39.9
Significance:	N: NS, Wv: NS, NxWv: NS				
	N= 0.1.67, Wv = 0.94, NxWv = 1.87,		CV%= 9.39		
			Combined (2004-2005 to 2006-2007)		
Debeira	33.3	38.8	37.9	36.8	36.7
Wadielneel	34.3	36.3	37.6	36.9	36.3
N main effect	33.8	37.6	37.8	36.8	
Significance:	N: ***, Wv: NS, NxWv: NS				
	N= 0.7, Wv = 0.37, NxWv = 0.75,		CV%= 22.3		

N=Nitrogen, Wv =Wheat varieties, N.S. = non significant at probability level
** *, **, * = significant at P < 0.001, 0.01 and 0.05, respectively
Different letters in a column under combined effects of three years indicate significant difference at p=5%

Table IV: Effect of nitrogen fertilizer application to a reclaimed salt-affected terrace soil on biomass yield (t/ha) of wheat (average of three cropping seasons)

Cultivars	Nitrogen level (kg/ha)				Wv main effect
	0	43	86	129	
			2004-2005		
Debeira	4.16±0.67	6.01±0.28	8.08±0.92	8.36±0.43	6.65
Wadielneel	2.17±0.72	3.89±0.27	4.57±0.84	5.83±0.80	4.12
N main effect	3.17	4.95	6.33	7.10	5.38
Significance:	N: *** Wv: *** N x Wv: NS				
	N= 0.41 , Wv = 0.31, NxWv = 0.63, CV% = 23.3				
			2005-2006		
Debeira	2.07±1.03	3.37±0.95	5.71±0.46	7.04±0.37	4.55
Wadielneel	1.63±0.52	4.34±0.86	5.59±0.51	6.44±0.28	4.50
N main effect	1.85	3.86	5.65	6.74	4.52
Significance:	N: ***, Wv: *, NxWv: NS				
	N= 0.47 , Wv = 0.16, NxWv = 0.33, CV%= 13.7				
			2006-2007		
Debeira	4.33±0.23	6.38±0.63	8.59±0.48	9.28±0.52	7.15
Wadielneel	4.07±0.30	6.17±0.49	7.65±0.28	8.63±0.45	6.63
N main effect	4.20	6.28	8.12	8.96	6.89
Significance:	N: ***, Wv: NS, NxWv: NS				
	N= 0.31 , Wv = 0.19, NxWv = 0.39 CV%= 11.4				
			Combined (2004-2005 to 2006-2007)		
Debeira	3.52c	5.92ab	7.46a	8.23a	6.28
Wadielneel	2.62c	4.80bc	5.94ab	6.97ab	5.08
N main effect	3.07	5.36	6.70	7.60	
Significance:	N: ***, Wv: ***, NxWv: NS				
	N= 0.23 , Wv = 0.13, NxWv = 0.27, CV%= 16.5				

Table V: Effect of nitrogen fertilizer application to a reclaimed salt-affected terrace soil on grain yield (t/ha) of wheat (average of three cropping seasons)

Cultivars	Nitrogen level (kg/ha)				Wv main effect
	0	43	86	129	
			2004-2005		
Debeira	1.43±0.51	2.65±0.45	3.14±0.38	4.64±0.18	2.97
Wadielneel	1.39±0.32	2.47±0.13	3.42±0.78	2.92±0.67	2.55
N main effect	1.41	2.56	3.28	3.78	2.76
Significance:	N: ** Wv: NS NxWv: NS				
	N= 0.23 , Wv = 0.25, NxWv = 0.51, CV%= 36.4				
			2005-2006		
Debeira	0.85±0.59	3.13±0.61	3.60±0.29	4.57±0.31	3.04
Wadielneel	0.29±0.06	2.72±0.63	3.27±0.19	4.30±0.13	2.65
N main effect	0.57	2.93	3.44	4.44	2.84
Significance:	N: ***, Wv: NS, NxWv: NS				
	N= 0.31 , Wv = 0.14, NxWv = 0.28, CV%= 19.5				
			2006-2007		
Debeira	1.69±0.17	3.76±0.26	4.87±0.18	5.26±0.29	3.90
Wadielneel	2.15±0.16	3.45±0.18	4.25±0.31	4.88±0.13	3.68
N main effect	1.92	3.61	4.56	5.07	3.79
Significance:	N: ***, Wv: NS, NxWv: NS				
	N= 0.18 , Wv = 0.18, NxWv = 0.19 CV%= 10.4				
			Combined (2004-2005 to 2006-2007)		
Debeira	1.32c	3.18b	3.87ab	4.82a	3.30
Wadielneel	1.28c	2.88b	3.64ab	4.03ab	2.96
N main effect	1.30	3.03	3.76	4.43	
Significance:	N: ***, Wv: **, NxWv: NS				
	N= 0.16 , Wv = 0.10, NxWv = 0.21, CV%= 22.3				

N=Nitrogen, Wv =Wheat varieties, N.S. = non significant at probability level
** *, **, * = significant at $P < 0.001$, 0.01 and 0.05, respectively
Different letters in a column under combined effects of three years indicate significant difference at p=5%

Table VI: Partial budget analysis of using 86 and 129 kg N/ha for wheat production in the reclaimed high terrace soils of the Northern State, Sudan

Item	Debeira			Wadielneel		
A. Total costs that vary (SDG/ha)	**86 kg/ha**	**129 kg/ha**	**Difference**	**86 kg/ha**	**129 kg/ha**	**Difference**
Cost of urea	193	290	97	193	290	97
Transportation to farm	10	14	4	10	14	4
Labor cost (application)	31	42	17	31	42	17
Total cost that vary(SDG/ha)	234	352	118	234	352	118
B. Benefits (SDG/ha)						
Average grain yield (t/ha)	3.87	4.82	0.95	3.64	4.03	0.39
Adjusted grain yield (t/ha)1	2.90	3.62	0.72	2.73	3.02	0.29
Field price (SDG/ha) 2	1000	1000	1000	1000	1000	1000
Gross benefits (SDG/ha)	2900	3620	720	2730	3020	290
Net benefits (SDG/ha)	**2666**	**3268**	**602**	**2496**	**2668**	**172**
MRR (%)		**510**			**146**	

1 Yield adjustment to 75% of total yield per ha of experiment results

2 Field price of wheat is calculated as the market price less harvesting, transportation and storage cost of the produce

SDG = Sudanese pound

Sensitivity analysis by increasing the total cost of production and reducing field prices of wheat by 25% indicated stability of both varieties with regard to input and output price fluctuations. The MRR changed to 266 and 47% for Debeira and Wadielneel, respectively. Wadielneel was found to be more susceptible to price changes than Debeira, which revealed high stability.

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