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Wheat Fertilization with Special Reference to Soil Properties and Groundwater Composition in Heavy Clay Soil from Egypt

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Abstract

Egypt is considered to be a heavy user of chemical fertilizers, especially NPK fertilizers. Thus, sustainable NPK-fertilizer management should be considered to minimize nutrient losses to the environment via volatilization or leaching. Therefore, the objectives of this study were to investigate the effect of different levels of NPK fertilization on some soil chemical properties, the chemical composition of groundwater and the yield and yield components of wheat plant under different treatments of NPK. Field experiments were carried out to study the effect of NPK application on soil properties and groundwater quality as well as wheat yield. Groundwater and soil samples were collected after the first, the third irrigation as well as after harvesting from each treatment for chemical analysis. The highest value of soil salinity was 1.64 dS m^{-1} after wheat harvesting compared to it before planting (1.13 dS m^{-1}). Values of pH after wheat harvesting ranged from 7.39 to 8.01 (7.67 before planting). Concentration of soluble cations in the ground water after harvesting was higher than it before planting. Concerning soluble salts, Na^+ and Cl^- was the dominate ions in the soil solution and cation concentration had the descending order: $Na^+ > Ca^{++} > Mg^{++} > K^+$ and anions had the following order: $Cl^- > SO_4^{--} > HCO_3^-$. The mean values of available N after wheat harvesting ranged from 8 to 19 mg N kg^{-1} (38 – 42 mg N kg^{-1} before planting). The highest value of available phosphorus after wheat harvesting was 11 mg P kg^{-1} (19.4 mg P kg^{-1} before planting). Available K ranged from 97 to 204 mg K kg^{-1} compared to it before planting (160 – 210 mg K kg^{-1}). The balance fertilization of NPK ($N_{80}P_{22}K_{50}$) gave the highest yield of wheat, improving soil fertility and decrease nutrient leaching to ground water. The grain yield of wheat was highly significant increased with increasing N levels up to 120 kg N $acre^{-1}$. The highest mean value of grain yield over the two seasons was 3.5 Mg $acre^{-1}$.

***Key words*:** wheat, groundwater composition, heavy clay soil, soil salinity, Egypt

1. Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal and forage crop all over the world and it is considered the main food crop in Egypt as in many other countries of the world. Due to the intensive use of chemical fertilizer and water in agriculture, which leads to both higher production cost and greater risk of environmental pollution, the ever-increasing target of food grain production is required. In 21st century, the major targets of global agriculture are to attain food security and environmental stability (**Behera and Panda, 2009a**). High application rates of water and NPK fertilizer lead to excessive leaching of them, making most of it unavailable to the plants and results in contamination of groundwater (**Behera and Panda, 2009b**). Leaching is often the most important process of NPK loss from the field soils to groundwater (**Chowdary et al. 2004**). In order to increase wheat crop production, it should maintain balance between the soil three basic nutrients NPK. Each of these three nutrients offers growing plant life, a specific benefit when used in the right proportions. In addition, balanced fertilization of NPK nutrients lead to increase soil fertility anti soil nutrients depletion and also decrease nutrients losses to ground water and hence decrease its pollution. Therefore, this research attempted to identifying the groundwater contribution to NPK-fertilization in irrigated wheat to improve the NPK fertilization strategies for wheat and to reduce threats of the environment pollution.

2. Materials and Methods

Two field experiments were carried out, in the Experimental Farm of Faculty of Agriculture, Kafrelsheikh University, during two successive growing seasons using wheat plant (cv. Sakha 93). The main plots were randomly assigned to N levels (0, 40, 80 and 120 kg N $acre^{-1}$ as NH_4NO_3), the subplots were represented by the two levels of phosphorus (0 and 22 kg P_2O_5 $acre^{-1}$ as super phosphate) and the sub sub-plots were represented by two levels of potassium (0 and 50 kg K_2O $acre^{-1}$ as K_2SO_4). Nitrogen fertilizer was divided in to four doses: 20% at sowing, 50% before the first irrigation, 20% before the second irrigation and the rest 10% was added at the third irrigation. Phosphorus and K were added during land preparation. A heavy clay soil (51.5% clay) used with pH = 8.05, EC = 3.7 dS m^{-1}, OM = 17 g kg^{-1}, CEC = 40.5 cmol kg^{-1} and available NPK: 40, 19, 185 mg kg^{-1}, respectively (**Table 1**). Physical and chemical soil properties were analyzed using standard methods according to **Klute (1986)** and **Page et al. (1982)**, respectively.

Table 1: Selected some soil physico-chemical properties of the experimental farm (0-25 and 25-50 cm) before planting

Growth season	Soil depth (cm)	Soil pH	EC dS m^{-1}	CEC, $cmol_c$ kg^{-1} soil	SOM, g kg^{-1}
First season	0-25	7.95	3.95	38.5	21.0
	25-50	8.06	4.66	32.9	17.7
Second season	0-25	8.10	3.45	43.0	12.8
	25-50	8.40	3.75	38.0	9.4

CEC = Cation exchange capacity, SOM = soil organic matter

Water samples were collected before and after each irrigation from canal of irrigation and drains as well as the drainage and groundwater by Augar method from the agriculture location (**Table 2**).

The obtained data were subjected to analysis of variance according to **Gomez and Gomez (1984).** Treatment means were compared by Duncan's Multiple Range Test. All statistical data were performed using analysis of variance technique by mean of "**MSTAT**" computer software package.

Table 2: Analysis of irrigation and drainage water before planting

Growth season	Water sample	pH	EC, dS m^{-1}	Available N, mg L^{-1}	Soluble P (mg L^{-1})
First season	IW	7.71	0.62	0.09	28
	DW	8.01	1.07	1.52	32
Second season	IW	7.63	0.63	0.08	26
	DW	7.68	1.20	1.75	29

IW = Irrigation Water
DW = Drainage Water

3. Results and Discussion

3.1 Soil reaction (pH)

The objectives of the present study were to investigate the effect of different levels of N, P and K fertilization on some soil chemical properties, the chemical composition of ground water and the yield and yield components of wheat plant.

The values of pH have regular trends, were increase with depth. The lowest value of soil pH was found in the surface layer (0-25 cm) was 8.0 for $N_{40}P_0K_{50}$ treatment. The highest values of pH were recorded 8.6 for $N_{80}P_{22}K_{50}$ treatment before first irrigation. On the other side, before third irrigation the highest value of soil pH was 8.55 in (25-50 cm) for $N_{40}P_0K_{50}$ treatment. However, the highest value of soil pH was 8.68 for $N_{40}P_{50}K_0$ treatment and the lowest value of soil pH was 7.5 for $N_{80}P_0K_{50}$ treatment after wheat harvest. This may be due to the high values of soil organic matter content in the surface layer and decreasing with depth where decomposed it giving organic acids **(Nasr El-Din, 2001).**

Soil pH values after wheat harvesting were ranged from 7.90 to 8.50 for $N_{40}P_0K_0$ and $N_{40}P_{22}K_0$ treatments, respectively in the 1st season, while these values ranged in the 2nd season from 7.5 to 8.68 $N_{80}P_0K_{50}$ and $N_{40}P_{22}K_0$ treatments, respectively. In general, the effect of different NPK fertilization on the soil pH values could be distinguished in **Table 3**. These results indicated that, NPK fertilization effected indirectly on soil reaction through microorganisms activities.

3.2 Soil salinity (EC)

Accumulation of salts, especially around the root zone is considered as the main problem which faced the localized irrigation system to be applied in Delta soils. The values of electrical conductivity (EC, dS m^{-1}) at each soil depth of all treatments reflected both of accumulation and movements of salt. Total soluble salts are considered to be the main criteria of many factors affecting soil productivity. They reflect the efficiency of irrigation and drainage conditions (**FAO 1976).** After wheat harvesting, the values of soil salinity in the 1st season ranged from 0.38 to 2.5 dS m^{-1} for treatments $N_0P_0K_{50}$ and $N_{40}P_{22}K_{50}$, respectively. While, these values in the 2nd season ranged from 0.42 to 2.13 dS m^{-1} for treatments $N_{40}P_{22}K_0$ and $N_{40}P_{22}K_{50}$, respectively. It could be concluded that, soil salinity increased with increasing soil depth in both 1st and 2nd seasons and with graded increasing NPK fertilization, whereas in general after harvest, soil salinity decreased by increasing of irrigation number as in shown in **Table 3.**

Concerning soluble salts, Na^+ and Cl^- were the dominant ions in the soil solution and cations concentration had the descending order: $Na^{++} > Ca^{++} > Mg^{++} > K^+$ and anions had the descending order: $Cl^- > SO_4^{--} > HCO_3^-$. The highest values of soluble Na^+ were before 1st irrigation, 3rd irrigation and after wheat harvesting 25, 18.7 and 23.7 cmol L^{-1}, respectively. While the lowest values of Na^+ were 5.9, 4.6 and 4.5 cmol L^{-1} for before 1st irrigation, 3rd irrigation and after wheat harvesting, respectively.

Table 3: Soil pH, soil salinity (EC), cation exchange capacity (CEC) and available NPK as affected by NPK fertilization over two successive seasons

Soil sampling time	Soil pH	EC, dS m^{-1}	CEC, $cmol_c$ kg^{-1}	Soil available nutrient (mg kg^{-1}) N	P	K
Before planting	8.40	4.49	43.0	42.0	28.5	210
Before 1st irrigation	8.55	3.17	51.9	39.3	17.7	258
Before 3rd irrigation	8.48	3.05	50.7	22.7	14.2	220
After harvesting	8.59	2.17	49.4	17.9	10.3	196

pH (1:2.5 soil water suspension) and EC (1:5 soil water extract)

3.3 Cation exchange capacity

The highest value of cation exchange capacity (CEC) after wheat harvesting was 47.2 cmol kg^{-1} soil with $N_{40}P_0K_0$ treatment, while the lowest value of CEC was 33.7 cmol kg^{-1} soil with $N_0P_{22}K_{50}$ treatment in the first season. While in the second season, the values of CEC ranged from 50.6 to 36.2 cmol kg^{-1} soil with $N_{80}P_{22}K_0$ and $N_{80}P_0K_{50}$ treatments, respectively. The obtained data for CEC indicated that, CEC was almost decreased through wheat growth season where some cations can be desorbed from clay and organic matter to replenishment soil solution.

3.4 Soil available N, P and K

It is clear that, soil content of available N was decreased from the beginning growth season to the end of it, although addition of N fertilizer (**Table 3**). That means wheat plant needs big amount of N and also some of nitrogen leached to groundwater, where soil content of available N were 42.0, 17.9 mg N kg^{-1} before planting and after harvesting, respectively. These results agree with those obtained by **Nasr EL-Din** (**2001) and Alan et al. (2007**). The same trend was recorded for available P and K. The highest values of available P and K were decreased from 28.5 to 10.3 mg P kg^{-1} and from 210 to 196 mg K kg^{-1} before first irrigation and after wheat harvesting, respectively (**Table 3**).

3.5 Chemical composition of ground water

The presented data in **Table 4** show the highest value of EC for ground water samples was 1.64 dS m^{-1} under $N_{120}P_{22}K_0$ treatment. Whereas, the highest value of pH samples was 8.01 for $N_{40}P_{22}K_0$ treatment, while the lowest value of pH was 7.39 under $N_{80}P_{22}K_0$ treatment. Data presented also available N in the ground water during plant growth in the 1st season was more than it in the 2nd season. This may be due to the quantity of added irrigation water which was less in the 2nd growing season compared to it in the 1st season. On the other hand, the highest values of available P (28 and 25 mg P L^{-1}) in the ground water represented the same treatment ($N_{80}P_{22}K_0$) through the two growing season (**Table 4**).

3.6 Effect of NPK fertilizers on grain yield of wheat

Data in **Table 5** indicated that, the grain and straw yields of wheat were highly significantly increased with increasing nitrogen level up to 120 kg $acre^{-1}$. Also, these wheat yields significantly increased in the presence of potassium (50 kg K_2O $acre^{-1}$) than in its absence. These results were supported by the data obtained by **Abd-Allah et al. (1999)**, **Genaidy and Hegazy (2001)** and **Sing and Pathak (2003)**.

Table 4: Effect of NPK fertilizers on some characteristics of groundwater after wheat harvesting

Growth season	Water sample	EC, dS m^{-1}	pH	Available N, mg L^{-1}	Soluble P, mg L^{-1}
First season	W1	1.02	7.69	0.07	20
	W2	1.27	7.43	0.16	24
	W3	0.89	7.39	0.18	28
	W4	1.59	7.50	0.10	23
Second season	W1	1.14	8.01	0.08	14
	W2	1.50	7.80	0.09	20
	W3	1.30	7.92	0.10	25
	W4	1.64	7.71	0.09	22

W1, W2, W3 and W4= ground water was taken from following treatments $\mathbf{N_0P_0K_0}$, $\mathbf{N_{40}P_{22}K_0}$, $\mathbf{N_{80}P_{22}K_0}$ **and** $\mathbf{N_{120}P_{22}K_0}$, respectively

The number of spikes per square meter of wheat was highly significantly increased by increasing graded N, P and K levels. The recorded highest value for the 2nd growing season (555 spike m^{-2}) was obtained with 80, 22 and 50 kg N, P_2O_5 and K_2O $acre^{-1}$, respectively.

Table 5: Effect of different treatments of NPK fertilizers on wheat grain, straw yield and no. of spikes per m^2 for the second season

Treatment	Grain yield (Mg $acre^{-1}$)	Straw yield (Mg $acre^{-1}$)	Spike No. m^{-2}
$N_0P_0K_0$	2.28 h	2.09 h	216 g
$N_{40}P_0K_0$	3.96 ab	2.36 fgh	384 cde
$N_{80}P_0K_0$	4.19 abc	2.75 de	437 bc
$N_{120}P_0K_0$	3.61 ef	3.31 ab	412 bcd
$N_0P_{22}K_0$	2.96 g	2.11 h	311 f
$N_{40}P_{22}K_0$	3.99 abcd	2.49 efg	381 de
$N_{80}P_{22}K_0$	3.94 bcde	2.84 cde	425 bcd
$N_{120}P_{22}K_0$	3.87 cde	3.14 bc	445 b
$N_0P_0K_{50}$	3.71 def	1.68 i	420 bcd
$N_{40}P_0K_{50}$	4.05 abcd	2.65 ef	397 bcde
$N_{80}P_0K_{50}$	**4.36 a**	2.77 de	392 bcde
$N_{120}P_0K_{50}$	4.06 abcd	3.05 bcd	427 bcd
$N_0P_{22}K_{50}$	2.80 g	2.27 gh	325 f
$N_{40}P_{22}K_{50}$	3.44 f	2.63 ef	396 bcde
$N_{80}P_{22}K_{50}$	**4.31 ab**	3.18 bc	**555 a**
$N_{120}P_{22}K_{50}$	3.93 bcde	**3.52 a**	347 ef

N_0, N_{40}, N_{80}, N_{120} = 0, 40, 80 and120 kg N $acre^{-1}$, resp.
P_0, P_{22} = 0 and 22 kg P_2O_5 $acre^{-1}$, respectively
K_0, K_{50} = 0 and 50 kg K_2O $acre^{-1}$, respectively
Means followed by the same letter in each column are not significantly different at 5% level using Duncan's Multiple Range Test (n= 4)

4. Conclusion

It could be concluded that, in order to increase wheat crop production, it should maintain balance between the soil three basic nutrients (NPK). Each of these three nutrients offers growing plant life, a specific benefit when used in the right proportions.

When the proper NPK balance is maintained during plant growth cycles, the following results will occur: (1) greener and more abundant foliage, healthier growth and strength. (2) Optimal plant yield, larger and more healthy and (3) most important of all, strong vigorous root systems that enable plants to feed and drink more effectively, convert nutrients into energy while making plants grow faster, stronger and more resilient to pest issues and disease.

In addition, balanced fertilization of NPK nutrients lead to increase soil fertility anti soil nutrients depletion and also decrease nutrients losses to ground water and hence decrease its pollution.

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