Sustainability of Soil Fertility Status under Different Management Systems at Middle Egypt Region

Abd El Hadi, A. H.[1]; Abo EL-Enein R.[2]; Negm A. Y.[1] and Pala M.[3]
[1]Soils, Water and Environment Res. Institute, Agriculture Research Center, Giza, Egypt,
[2]Field Crops Res. Institute, Agriculture Research Center, Giza, Egypt
[3]International Center for Agricultural Research in the Dry Areas (ICARDA)

Received on: 31/10/2013 *Accepted: 15/12/2013*

ABSTRACT

Soil fertility status after two crop cycles of 3-years crop rotation was evaluated in a long-term trial (1995-2001) conducted at Middle Egypt Region (Sids Res. Stn) clay loamy soil; under different management systems, i.e. 4 levels of NPK fertilizers (0, low, recommended and high); water quality (fresh and drainage); water quantity (farmer and recommended level) and two crop rotations (prevailing and proposed).

Post harvest soil residuals of N, P and K after each crop cycle were significantly increased by increasing NPK fertilizer level and the obtained values after the second cycle surpassed those after the first cycle. Meanwhile the available Fe, Zn and Mn were generally reduced by NPK levels after the first cycle, however, there were a restoration in the concentrations of these micronutrients after the second crop cycle, since no differences in the residuals of these micronutrients between the zero-fertilized plots and those received NPK levels were detected after the second cycle.

- Under the proposed crop rotation (Rot. II), with intensive cropping system, soil residuals of the available N, P and K were higher than those of the prevailing one (Rot. I), while the soil residuals of Fe, Zn and Mn as well soil organic matter percentage was not affected by crop rotation.
- The available soil N and K contents after each crop cycle under the recommended water regime were higher than under the farmer regime, while the residual of P was not affected by water regime. Soil organic matter and Fe and Mn residuals were improved by recommended water regime after the second cycle.
- The residual soil-N of plots received drainage water was improved after each crop cycle as compared with those received fresh water, while the other nutrient residuals showed inconsistent results during the two crop cycles.

Key words: Crop cycle-Crop Rotation– NPK Fertilizer– Soil Fertility– Water Quality– Water Quantity.

INTRODUCTION

Agricultural production systems in Egypt are very intensive due to the favourable conditions that allow cropping during the whole year. To ensure the sustainability of the high productivity in the Nile Valley and the Delta, more research for better management and conservations of natural resources (soil and water) is needed including long-term trials since most agricultural research is being directed towards productivity enhancement.

Soil fertility enhancement and maintenance is a critical component of sustainable land management (SLM) as agriculture is the primary interface between humans and the environment. Specifically, a healthy soil with appropriate balance of air, minerals, water and organic materials is one of the key components of SLM and soil fertility improvement (Pieri and O'Connell, 1998).

In a long-term fertilizer treatments, (Singh 1998) in India (Martinovic et al. 1998) in Yogoslavia and (Abd El Hadi, et al. 2000) in Egypt indicated that there was a considerable build up of available N, P and K where plant nutrients (NPK) were applied and serious depletion of these nutrients where they were not applied. There was also a decrease in the status of micronutrients e.g. Fe, Mn, Zn, Cu, B and Mo. Also, the results by (Jayasree and Muthuvel 1998) proved that even in K rich soils, K addition is essential for sustainable soil fertility. However, continuous crop removal for K without replenishment is likely to cause an irreparable damage from the soil fertility point of view.

Intensive cropping for high yield caused heavy depletion of exchangeable and non-exchangeable K in alluvial soils, particularly in the absence of K fertilizing (Tiwari, 1985). In sandy loam soil, (Sharma and Arora 1988) reported that application of P and K increased their respective residual availability by about twofold, however the applied N did not significantly increase available N content in the soil. Mercik (1989) revealed increases in soil exchangeable K content by high K rates, but this effect was observed throughout the whole soil profile only at the end of the second rotation. Panique et al. (1997) also showed that post-harvest soil K was increased as a sequence of K fertilization.

Pokorny and Strakovar (1998) reported that correct integration of cereals in crop rotation significantly affected nutrient utilization from soil reserves and soil fertility. Among the studied variants, the best one appears to be winter wheat after clover, which justifies the growing of perennial forge crops in crop rotation (Malhi et al. 1998) implicated that grasslands can be managed by N fertilizer addition to sequester more carbon from the atmosphere and store it in the soil.

The main objective of this long-term study is to promote sustainability of soil fertility for high productivity by the proper inputs (chemical fertilizers and water) and intensive cropping systems in Middle Egypt region.

MATERIALS AND METHODS

The long-term trial (LTT) was initiated in winter growing season of 1995/96 and lasted until the summer growing season of 2001(Two crop cycles with 3-year crop rotation for each) were carried out at Sids Agricultural Research Station to evaluate the following four tested factors:

1-chemical fertilizers: Balanced NPK fertilizers according to crop requirements (Table, 1) were added at four levels, i.e. zero (0), low (L), medium (M) and high (H). Phosphorus fertilizer levels as Ca-superphosphate (15% P_2O_5) were applied preplanting for all crops while K fertilizer was applied to certain crops (onion, soybean, tomato and cow pea) as K-sulphate (48%K_2O) before the first irrigation. Nitrogen fertilizer levels were applied at the proper time for each grown crop as Urea 46.5% N or Ammonium nitrate 33.5% N.

2- Crop rotation: Two types of 3-year crop rotation were followed in each of the two crop cycles as follows:

Year-1	Year-2	Year-3
Prevailing rotation (Rot. I)		
Catch berseem	Wheat	Faba bean
Cotton	Maize	Tomato
Proposed rotation (Rot.II)		
Onion (relay)	Early wheat	Faba bean
Cotton	Soybean	Tomato
	Cowpea	

3- Irrigation water quantity: (a) Recommend level (RL) which is the amount of water applied to replenish crop evapotranspiration (ET) + 20% ET as a leaching factor and (b) Farmer level (FL) which is RL + 30% RL as excess water.

4- Irrigation water quality: (a) Fresh water (FW) from the irrigation canal and (b) Drainage water (DW) from the closest drain to the experiment site. The experimental design was split-split block in three replicates with plot size of 108 m^2 (9m×12m). Soil surface (0-30 cm) samples were collected from each experimental plot after each crop cycle of 3-year crop rotation and subjected to chemical analysis for the available macronutrients (N, P and K) according to (Jackson 1973), micronutrients (Fe, Zn, and Mn) according to (Lindsay and Norvell, 1978) and soil organic matter content according to (Walkley and Black 1934). Average values from the three replications of each treatment were interpreted using the analysis of variance (ANOVA) with separation of means accomplished by using LSD at 5%.

RESULTS AND DISCUSSION

1- Effect of NPK fertilizer:

Irrespective of crop rotation, water quality and water quantity, the amount of available soil N and P after each crop cycle were significantly increased by increasing fertilizer level (Table 2 and Fig. 1). Meanwhile, soil K was significantly augmented by different fertilizer levels after the first cycle with no significant difference between the low and the medium levels, while only the high fertilizer level recorded significant increase in soil K over the 0-fertilizer plots after the second cycle. This could be due to the existence of dynamic equilibrium among the various forms of K in the experimental soil. The improved soil fertility status as a sequence of fertility confirms the important role of chemical fertilizers to preserve soil fertility and productivity and to prevent land degradation. So plant nutrient taken up by crops must be replenished through the application of balanced fertilizers. Also the use of balanced fertilization contributes to soil organic matter maintenance, water holding capacity, biological N fixation, and soil erosion control, other physical and chemical properties, and less extensive land use.

Contrary to the residual of the macronutrients (N, P and K), the available Fe, Zn and Mn were generally reduced by NPK fertilizer application particularly the highest level after the first crop cycle and Mn showed pronounced decreases. This could be attributed to the large vegetative growth with extended root systems that developed which had utilized these micronutrients without any compensation. However, the restoration in the concentrations of these micronutrients were noticed after the second crop cycle, since no significant changes in the residuals of soil Fe, Zn and Mn relative to the zero–fertilized plots were detected after the second crop cycle due to NPK fertilization. Soil- Zn content fell in the medium range and Fe and Mn are still adequate for most the immediate crops. Inadequacy of these micronutrients is expected especially under high NPK levels. On the other hand, soil organic matter content, after each crop cycle, was ameliorated by NPK fertilizer application and showed higher values after the second crop cycle. This may be due to the fertilizer contribution to soil organic matter intendance through enhancing good root systems and soil micro-organisms.

Table 1: Fertilizer rates (kg/ha) for the grown crops

Crop	Low			Medium			High		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Winter crops									
Wheat	83.3	17.8	-	166.6	35.7	-	249.9	53.6	-
Berseem	23.8	23.8	-	47.6	47.6	-	71.4	71.4	-
Faba bean	23.8	35.7	-	47.6	71.4	-	71.4	107.1	-
Onion	95.2	17.8	35.7	190.4	35.7	71.4	285.6	53.6	107.1
Tomato	142.8	47.6	57.1	285.6	95.2	114.2	428.4	142.8	172.6
Summer crops									
Maize	142.8	23.8	-	285.6	47.6	-	428.4	71.4	-
Cotton	59.5	23.8	-	119.0	47.6	-	178.5	71.4	-
Soybean	35.7	23.8	35.7	71.4	47.6	71.4	107.1	71.4	107.1
Sunflower	47.6	23.8	-	95.2	47.6	-	142.8	71.4	-
Cowpea	35.7	35.7	35.7	71.4	53.6	71.4	107.1	71.4	107.1
Rotation I				952	345.1	114.2			
Rotation II				975.8	380.8	257.0			

Table 2: Effect of NPK levels on soil contents of macro- and micronutrients (ppm) and OM (%) after two crop cycles of 3-ycear crop rotation at Sids Research station.

Fert	First cycle (1995/96-1997/98)							Second cycle (1998/99-00/01)						
Level	O.M	N	P	K	Zn	Fe	Mn	O.M	N	P	K	Zn	Fe	Mn
O	1.70a	30.2a	6.55a	298a	0.74b	8.58c	6.43c	2.08	36.8a	8.4a	377a	0.80	6.8	5.6
Low	1.74b	57.5b	11.45b	331b	0.72b	7.69b	4.64b	2.16	94.3b	19.6b	393a	0.82	6.3	5.6
Medium	1.80c	87.4c	15.40c	359b	0.70b	7.38b	3.89ab	2.16	128.0c	27.9c	391a	0.83	6.5	5.5
High	1.78d	133.9d	22.90d	429c	0.68a	7.09a	3.38a	2.19	174.0d	33.8d	415b	0.81	6.5	5.5

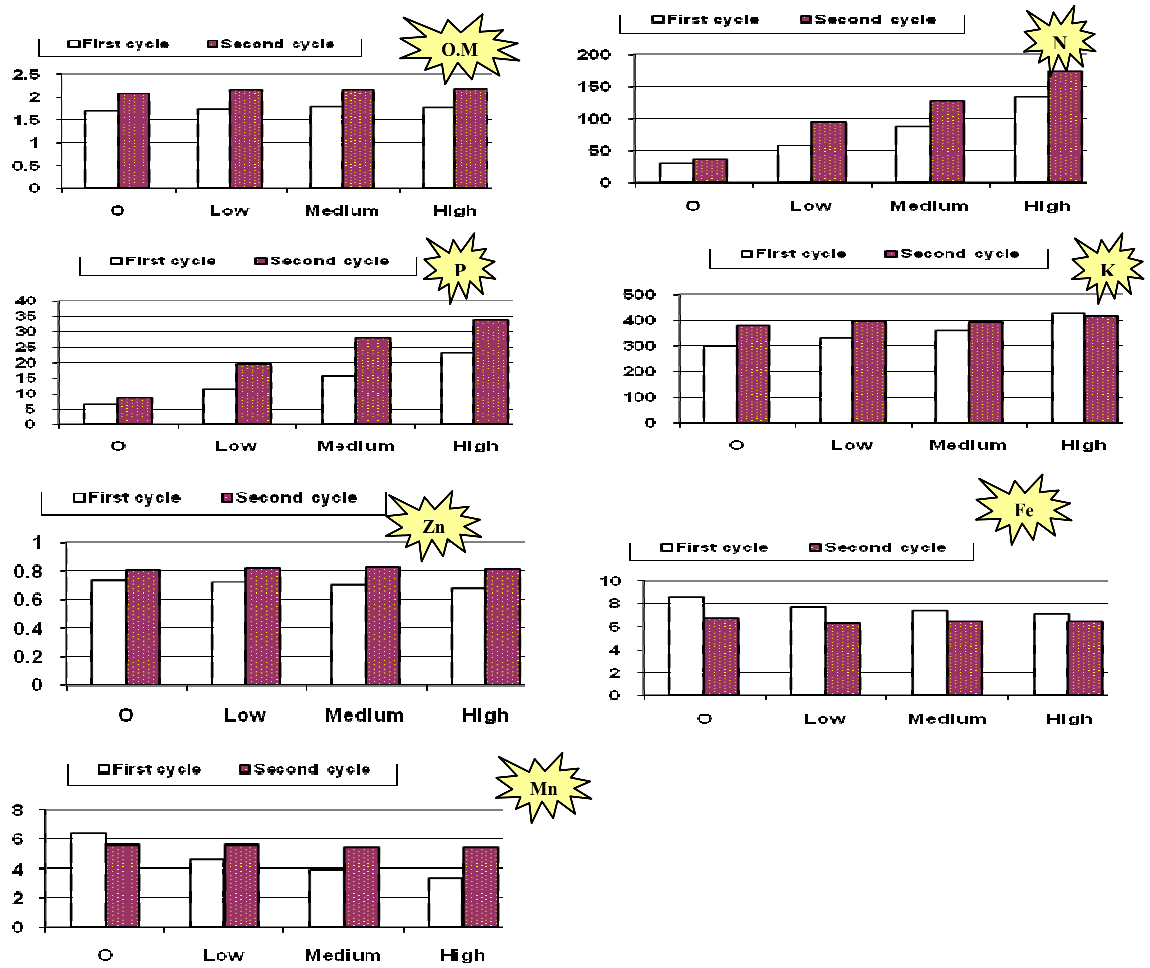

Figure 1: Effect of NPK levels on soil contents of macro- and micronutrients (ppm) and OM (%) after two crop cycles of 3-year crop rotation at Sids Research station.

2- Effect of crop rotation:

The residual soil contents of N, P and K after each crop cycle were also affected by crop rotation and the second cycle recorded higher values for macronutrients than those of the first cycle. These macronutrients were improved under the recommended rotation (Rot. II) compared to the prevailing one (Rot. I) by 17.91, 36.4 and 23.6% for N, P and K respectively after the first cycle and by 14.7, 46.7 and 17.6% after the second cycle as shown in (Table 3 and Fig. 2). These increases could be attributed to the intensive cropping system followed in Rot. II, which received more fertilizer amounts than Rot. I. Also, Rot. II comprised more leguminous crops than Rot. I, and thus biological N fixation by these crops may be improved in Rot. II. The higher nutrient contents of Rot. II plots may be also due to the crop sequence in this rotation, since root exudates of different plant species can increase nutrient availability in the soil by chemical mobilization (Trehan and Classen, 1998).

Soil chemical analysis after each crop cycle showed that the amount of available Fe, Zn and Mn contents as well as the soil organic matter percentage were not or slightly affected by crop rotation as shown in (Table 3 and Fig. 2).

Table 3: Effect of crop rotation on soil contents of macro-and micronutrients (ppm) and OM(%) after cycle of 3-year crop rotation at Sids Research station.

Crop Rotation	First cycle (1995/96-1997/98)							Second cycle (1998/99-00/01)						
	O.M	N	P	K	Zn	Fe	Mn	O.M	N	P	K	Zn	Fe	Mn
I	1.84	70.9	12.1	316.4	0.72	7.61	4.81	2.16	101.0	18.2	362.2	0.80	6.7	5.8
II	1.84	83.6	16.5	391.0	0.70	7.91	4.36	2.15	115.8	26.7	426.0	0.82	6.7	5.2

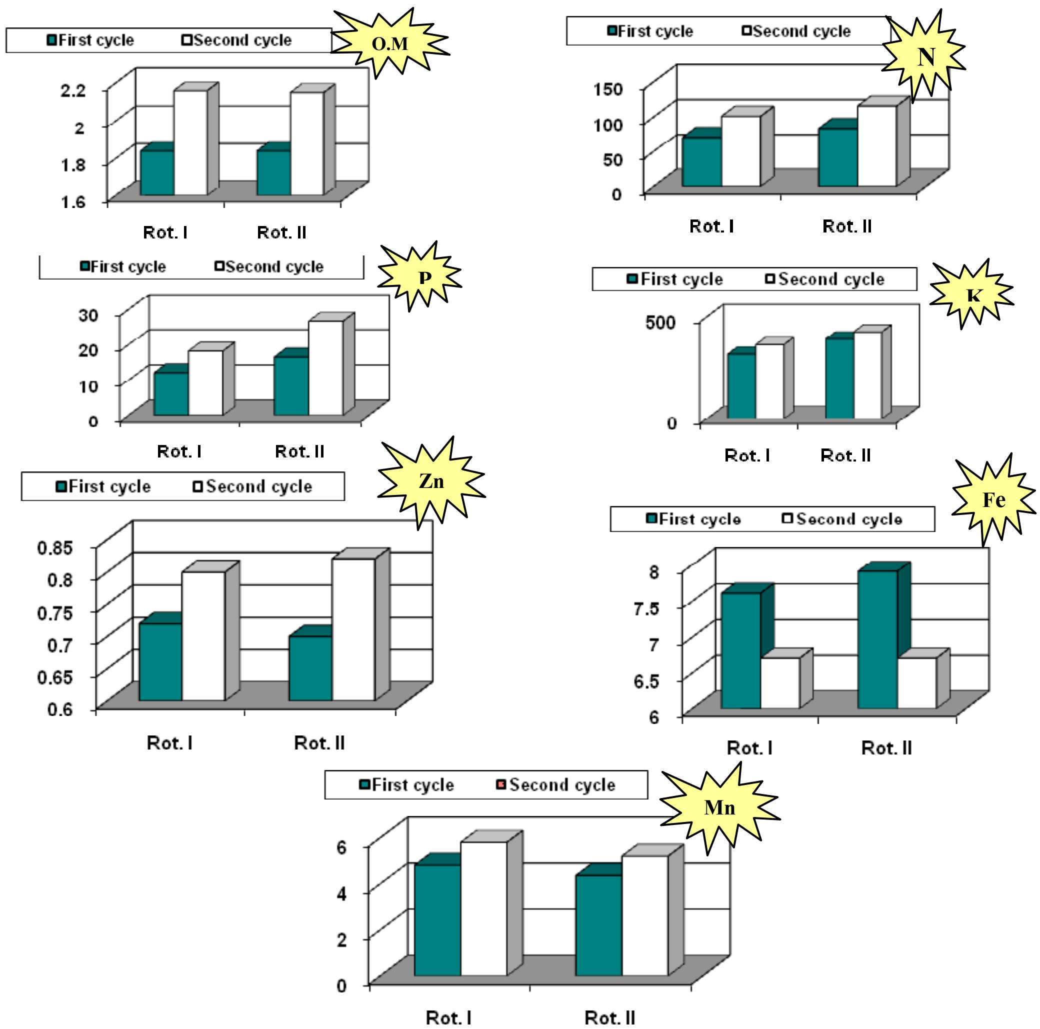

Figure 2: Effect of crop rotation on soil contents of macro-and micronutrients (ppm) and OM(%) after two crop cycles of 3-year crop rotation at Sids Research station.

3.3 Effect of irrigation water quantity:

The recommended irrigation water regime showed higher N and K residuals in soil after each crop cycle compared with the farmer regime and the increases were significant after the second crop cycle (Table 4). This indicates the nutrient losses, especially N, by excess irrigation water of the farmer level through leachability process. The residual soil P, on the other hand, after each crop cycle was not affected by irrigation water regime, may be due to the low mobility of P through soil profile and hence its low leachability. The Fe, Zn and Mn soil residuals as well as soil organic matter percentage after the first cycle were not affected by irrigation water regime. However, Fe and Mn residuals and soil organic matter content showed significant increases by the recommended water regime as compared with the farmer regime as shown in Table 4 and Fig. 3.

Table 4: Effect of irrigation water quantity on soil contents of macro-and micronutrients (ppm) and OM(%) after cycle of 3-ycear crop rotation at Sids Research station.

Water	First cycle (1995/96-1997/98)							Second cycle (1998/99-00/01)						
Level	O.M	N	P	K	Zn	Fe	Mn	O.M	N	P	K	Zn	Fe	Mn
Farmer	1.82	74.6	13.5	346	0.71	7.71	4.74	2.11a	105.5a	21.6	386.0a	0.83	6.1a	5.2a
Recomm.	1.81	79.9	14.6	363	0.71	7.80	4.43	2.19b	111.8b	23.2	402.3b	0.79	6.9a	5.8b

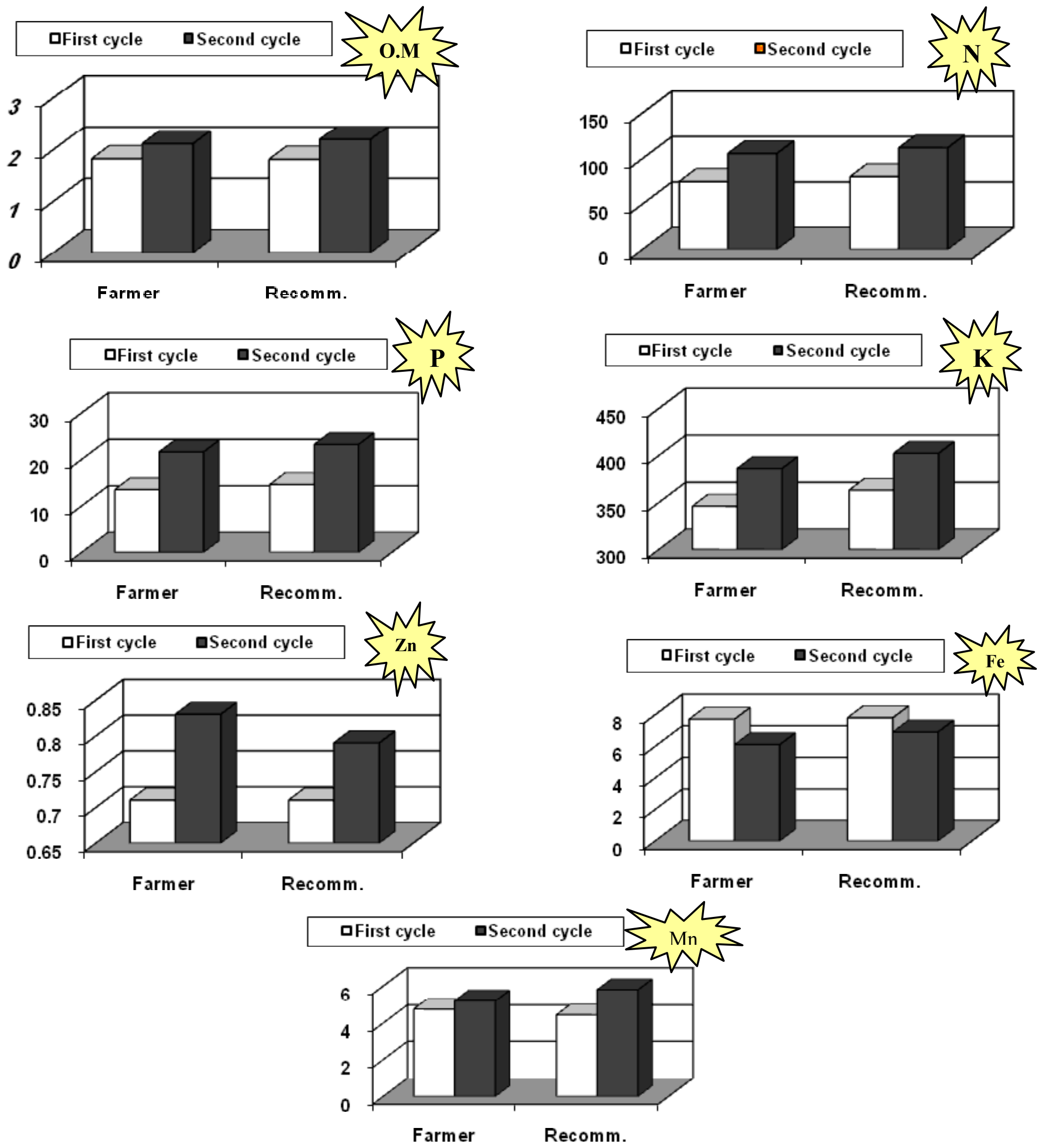

Figure 3: Effect of irrigation water quantity on soil contents of macro-and micronutrients (ppm) and OM(%) after two crop cycles of 3-year crop rotation at Sids Research station.

4-Effect of water quality:

It was noticed that the residual N after each crop cycle for the plots that received drainage water was slightly higher than those of irrigated with fresh water. This may be attributed to the leached NO_3 in drainage water. On the other hand, irrigation water quality showed inconsistent results for the residuals of both P and K during the two crop cycles as shown in (Table 5 and Fig. 4). Also, soil organic matter percentage and the available soil contents of Fe, Zn and Mn were not affected by irrigation water quality after each crop cycle, except the residual Fe which was significant increase in the plots that received the drainage water for crop rotation II.

Table 5: Effect of irrigation water quality on soil contents of macro-and micronutrients (ppm) and OM (%) after cycle of 3-ycear crop rotation at Sids Research station.

Water Quality	First cycle (1995/96-1997/98)							Second cycle (1998/99-00/01)						
	O.M	N	P	K	Zn	Fe	Mn	O.M	N	P	K	Zn	Fe	Mn
Fresh	1.88	73.3	14.6	354	0.71	7.70	4.65	2.17	106.6	20.9	385.6a	0.84	5.92a	5.45
Drainage	1.75	81.2	13.6	325	0.71	7.80	4.52	2.17	110.0	24.0	402.4b	0.78	7.05b	5.65

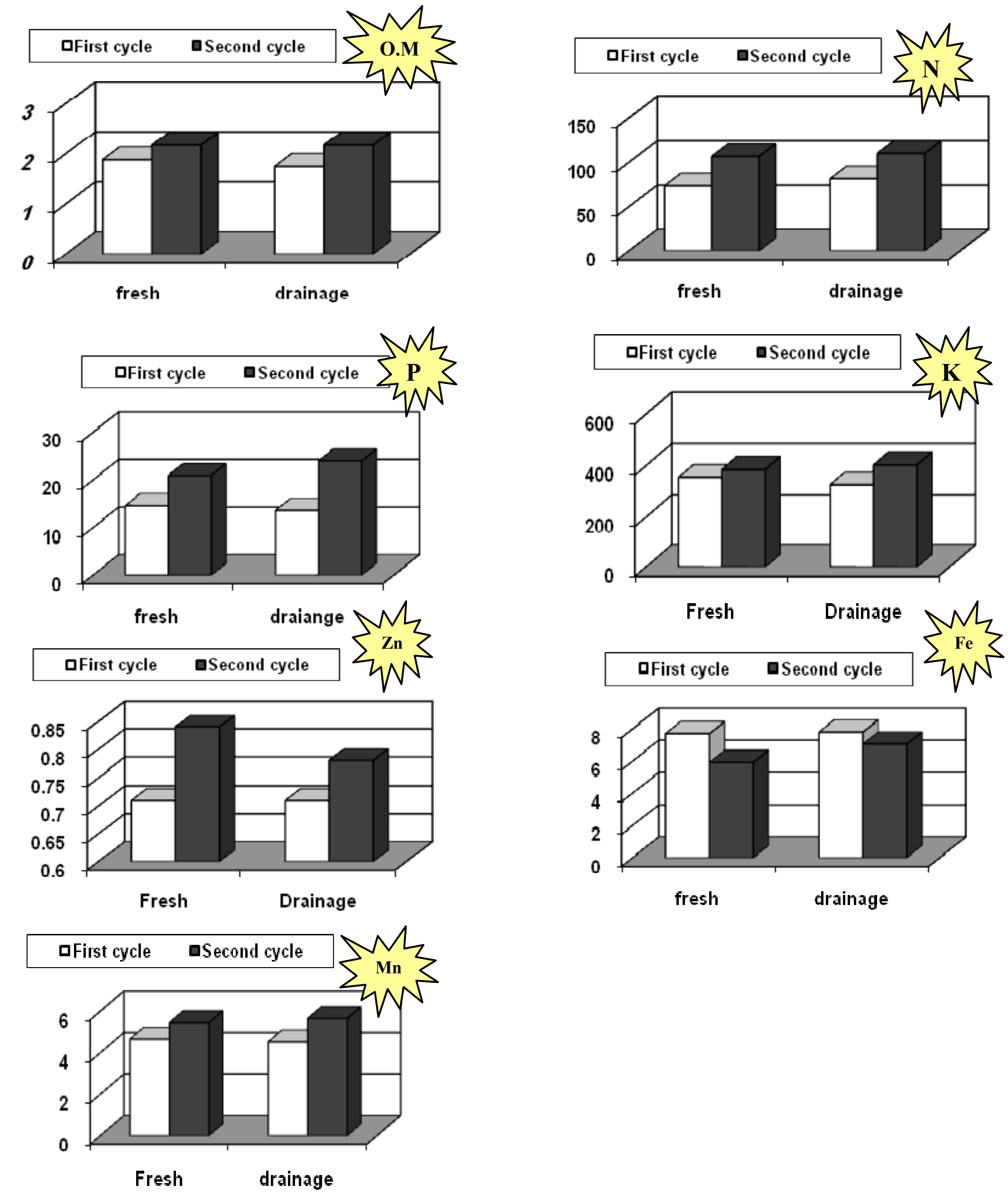

Figure 4: Effect of irrigation water quality on soil contents of macro-and micronutrients (ppm) and OM (%) after two cycles of 3-year crop rotation at Sids Research station.

Table 6: Relative contribution (%) of the tested factors on the soil residuals of macro-and micronutrients after the first crop cycle of 3-year crop rotation.

Factors	N	P	K	Zn	Fe	Mn
Fertilization	90.56	81.11	50.06	17.35	47.06	73.72
Crop rotation	2.45	8.72	21.05	4.58	1.80	2.83
Water quantity	0.14	1.16	5.27	2.30	0.40	1.55
Water quality	0.96	0.24	14.38	2.77	6.23	0.34
Total	94.11	91.23	90.76	27.00	55.49	78.44

5- Relative contribution effect of the tested factors on soil fertility:

The relative contribution (RC %) effect of each tested factor on the sustainability of soil fertility was statistically evaluated after the first crop cycle according to Steel and Torrie (1960). Among the affecting factors, the added fertilizers showed the greatest RC on the soil residuals of both macro-and micronutrients (Table 6).

The RC was in the following decreasing order for macronutrients, N>P>K and micronutrients: Mn>Fe> Zn.

The RC of crop rotation was K>P>N and Zn>Mn> Fe, while both water quality and quantity recorded very small RC on N and P. On the other hand, water quality showed higher RC on residual K compared to N and P. Crop rotation, water quality and quantity showed less RC on micronutrients.

REFERENCES

Jackson, M.L. (**1973**). Soil chemical analysis. Printice Hall of limited. Printice New Delhi.

Jayasree, S. and Muthuvel P. (**1998**). Potassium for soil fertility 16 th. World congress of soil Sci, 20-26 Aug. 1998, Montpellier, France

Lindsay, W.L and Norvell W. A. (**1978**). Development of a DTPA soil test for zince, manganese and copper. Soil Sci. Soc. Amer. J., **42**:421-428.

Malhi, S.S.; M. Nyborg; Harabiak J.T., G.M. Monreal and Gregorich E.G (**1998**). Influence of long-term N fertilization on quantity and quality of organic C stored in a grassland soil. 16th. World congress of soil Sci., 20-26 Aug. 1998 Montpellier, France.

Martinovic, L., D. Stevanovic and Zdravkovic M. (**1998**). Effect of long-term fertilization on chemical changes of pseudogley soils. 16th. World congress of soil Sci., 20.26 Aug. 1998, Montpellier, France.

Mercik, S. (**1989**). Direct and residual effect of periodically high potassium rates on plants and soil. Roczniki – Nauk - Rolniczych - Seria – A-produkcja- Roslinna **108(1)**: 37-48.

Panique, E., Kelling K. A. and Schulte E.E. (**1997**). Potassium rate and source effects on potato yield, quality and disease interaction. American Potato Journal. **74**:379 -398.

Pieri, C. and Connell P. O (**1998**). Soil fertility improvement, key connection between sustainable land management and rural well being. 16th. World congress of soil Sci., 20-26 Aug. 1998, Montpellier, France.

Pokorny, E. and Straikovar R. (**1998**). Soil as a nutrient transformer in crop rotation. 16th. World congress of soil Sci., 20-26 Aug. 1998, Montpellier, France.

Sharma, V.C. and Arora B.R. (**1988**). Residual effect of applied nitrogen, phosphorus and potassium to potato on the soil properties. Journal of the Indian Society of soil Sci., **36(1)**: 106-112.

Singh, K.P. (**1998**). Effect of long-term application of fertilizer manure, lime and weedicide on crop yields and fertility status in an acid upland soil of Chotangpur, Bihar, India. 16th. World congress of soil Sci., 20-26 Aug. 1998, Montpellier, France.

Steel, R. G. D. and J. H. Torrie (**1960**). Principles and procedure of statistics. Mc Graw Hill. New York.

Tiwari, K.N. (**1985**). Changes in potassium status of alluvial soils under intensive cropping. Fertilizer News **30 (9)**: 17-24.

Trehan, S. P. and Classen N.(**1998**). Potassium efficiency of potato, wheat and sugar beet grown in soil as related to root and shoot parameters. 16th World congress of soil Sci., 20-26 Aug. 1998, Montpellier, France.

Walkley, A. and Black T. A. (**1934**). An examination of Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Sci., **37**:29-38.

الملخص العربى

استدامة حالة خصوبة التربة تحت ظروف نظام ادارة مختلفة فى اقليم مصر الوسطي

عبدا همام عبد الهادى[١]، رشاد ابو العينين[٢]، عبد الواحد نجم[١]، مصطفي بالا[٣]
[١]معهد بحوث الاراضي والمياه والبيئة- مركز البحوث الزراعية- الجيزة- القاهرة
[٢]معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية- الجيزة - القاهرة
[٣]المركز الدولي للزراعة فى المناطق الجافة (ICARDA) صندوق بريد ٥٤٦٦ حلب سوريا

قيمت حالة خصوبة التربة بعد تطبيق دورتين محصوليتين لتعاقب محصولي لمدة ٣ سنوات فى تجربة طويلة الامد فى الفترة من(١٩٩٥-٢٠٠١) اقيمت فى اقليم مصر الوسطى(محطة بحوث سدس) فى ارض طينية لومية تحت ظروف ادارة مختلفة للموارد على سبيل المثال هناك ٤ مستويات من التسميد المتزن باسمدة النتروجين والفوسفور والبوتاسيومNPK (صفر، منخفض، موصي به، مرتفع)، مستويين لجودة مياه الري (مياه ري، مياه صرف زراعي) ومستويين لكمية مياه الري (معاملة المزارع، معاملة موصي بها) وأخيراً تعاقبين محصوليين (سائد، مقترح).

بعد انتهاء حصاد كل دورة محصولية لوحظ ان مستوى المتبقي من عناصر NPK زاد معنويا بزيادة مستوى التسميد وكانت الارقام المتحصل عليها بعد الدورة الثانية اكبر من المتحصل عليها بعد الدورة المحصولية الاولي. وفى نفس الوقت كان مستوى العناصر الصغري: الحديد Fe، الزنك Zn، والمنجنيز Mn المتيسرة منخفضاً بعد الدورة المحصولية الاولي مع مستويات عناصر النيتروجين والفوسفور والبوتاسيوم بينما كان هناك استعادة فى تركيز هذه العناصر الصغري بعد الدورة المحصولية الثانية، حيث لم يكن هناك فرق فى المتبقي من العناصر الصغري بين المعاملة بدون تسميد والمعاملات التى حصلت على مستويات متزايدة من عناصر النيتروجين والفوسفور والبوتاسيوم.

تحت ظروف التعاقب المحصولى المقترح (Rot2) حيث كان نظام محصولى مكثف فان المتبقى فى الأرض من عناصر النتروجين والفوسفور والبوتاسيوم كان بمستويات اعلى من ما هو فى التركيب المحصولى السائد (Rot1). بينما كان المتبقى من الحديد والزنك والمنجنيز وايضاً محتوى المادة العضوية غير متأثر بالتعاقب المحصولى.

كان المتيسر من النتروجين والبوتاسيوم بالارض بعد كل دورة محصولية تحت معاملة الرى الموصى بها اعلى من معاملة رى المزارع، بينما كان المتبقى من الفوسفور غير متأثر بأدارة المياه. تحسنت متبقيات المادة العضوية والحديد والمنجنيز بتطبيق كميات مياه الرى الموصى بها بعد الدورة المحصولية الثانية.

فى الأحواض التى حصلت على مياه صرف زراعى تحسن مستوى النتروجين المتبقى فى الأرض بعد كل دورة محصولية بالمقارنة بالتى حصلت على مياه رى. بينما اظهر المتبقى من العناصر الأخرى نتائج متضاربة خلال الدورتين المحصوليتين.