Sustainability of Soil Fertility Status after Two Crop Cycles of 3-Years Crop Rotation in Calcareous Soils in Egypt

Abd El Hadi, A. H[1].; Abo EL-Enein, R.[2]; Awad, A.M. [1]; El-Shebiny, G.M. and Moursy, M.E.
[1] Soils, Water Environment Res. Institute; Agriculture Research Center, Giza, Egypt
[2] Field Crops Res. Institute; Agriculture Research Center, Giza, Egypt,

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ABSTRACT

A long-term field trial was conducted under surface irrigation system at west Nile Delta Region (Nubaria Res. station) which represent a large area of sandy and sandy loam calcareous soils with calcium carbonate ranging between 20 to 40%, during 1996/97 until 2001/2002 under different resource managements i.e. 4 levels of balanced N P and K (zero, low, medium, and high), with and without organic manure application, water quantity(farmer and recommended irrigation water levels) and two crop rotations (prevailing and proposed). Soil samples were taken at starting of the experiment (zero-time) and after the first and second cycle of the 3-years crop rotation to follow up the concentration of available macro-and micronutrients and organic matter content. The obtained results indicated that:

1. The available residual of N, P and K were significantly increased by increasing the applied N, P and K levels after the first and second cycles, while those of Fe, Mn and Zn were not significantly affected.
2. Application of organic manure also improved soil content of N, P, K, O.M, Fe, Zn and Mn after the second cycle of 3-years crop rotation. On the average, application of organic manure increased N, P, K, O.M, Fe, Zn and Mn contents by about 16.5%, 43.5%, 16.5%, 51%, 18%, 26% and 16.5% respectively over zero organic manure application.
3. The proposed crop rotation showed significant increase in N residual only over the prevailing one, but P and K residuals were not affected after the first cycle, while after the second cycle, P and K residuals were significantly increased under the proposed crop rotation, but O.M% and N-residual were eligibly improved.
4. Fe and Mn residuals showed lower values in the second cycle compared to the first one, may be due to the amounts removed by crops during the two cycles of 3-years of crop rotation.
5. The available soil content of N, P and K were improved under the application of the recommended water regime compared to the farmer level after the first and the second cycle.
6. The added organic manure showed the greatest relative contribution RC% on organic matter by 85.92%; macro-and micronutrient for N, P and K residuals by 23.1%, 75.0% and 56.7% respectively, while it recorded 39.1%, 25.5% and 6.0% for Zn, Mn and Fe respectively. Application of N, P and K fertilizers showed RC% only for the corresponding nutrient by 66.8%, 18.6% and 32.9% for N, P and K respectively. Meanwhile, water quantity showed RC% of 2.03% for P and 6.18% for organic matter content, while crop rotation showed RC% of 3.34% for N and 8.46% for Mn.

Key words: crop cycle – crop rotation – NPK fertilizer - soil fertility – water quantity organic manure.

INTRODUCTION

Soil fertility is related to the soil biological chemical and physical properties, whose individual components may be difficult to define and quantify, which often interact in complex and little to understand as ways and changes only slowly, if at all, over time. For example, the proportion of sand and clay sized particles cannot be changed except at great cost by soils mining. For this reason, long-term trial offers the great opportunity to study and to document long-term changes of soil and plants of specific site by means of adjacent variants of fertilization and land use. For example, a long-term trial has allowed checking to what extent methods of soil and plant analysis give realistic values of the soil nutrients supply to plants. In addition, if can be determined how different fertilizers in long-term affect the formation of organic-mineral complexes in the soil and thus the soil structure (El-Leboudi, *et al.* 1970 , Leiweber and Reuter, 1992, Kahle and Kretschmer 1994). Such investigations contribute to the understanding confirmation of scientific predictions.

Under intensive cropping system in the subtropics, large amount of plant nutrients are removed by the crops and thus a gradual decline in soil fertility. In a long-term fertilizer treatments, in India (Singh, 1998), in Yugoslavia (Martinovic, 1998), in Egypt (Abd El Hadi, *et al,* 2000) and in Bangladesh (Miah 2000) indicated that there was a considerable build up of available N, P and K where the 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 Fe, Zn, Mn, B, Cu and Mo.

Fertilizer application in conjunction with organic manure shows better stability in production under multiple cropping systems than the use of the chemical fertilizer alone. The effect of organic residues on yields of crops is primarily due to supply of nutrients and also to improving soil physical environment (Nambiar and Abrol, 1989;

Aggarwal and Ven Kateswarlu, 1998; Pokorny and Strlkover, 1998).They reported that correct integration of cereals in crop rotation significantly affected nutrient utilization from soil reserves and soil fertility.

The soil in the western part of the Nile-Delta is mainly calcareous soils with high content of calcium carbonate, low concentration of macro-and micronutrients as well as low content of soil organic matter. A long-term field trial was conducted tojnh study the effect of two crop rotations, irrigation water quantity, and different levels of NPK with and without organic manure ap,lication on the sustainability of soil fertility on the calcareous soil.

MATERIALS AND METHODS

A long-term trial (LTT) was conducted in the growing season (1996/1997) and lasted until (1998/1999) for the first cycle of the 3-years crop rotation and lasted for the second cycle until (2001/2002) at Nubaria Agricultural Research station in the western part of the Nile-Delta to evaluate the following 4 tested factors:

2.1 Irrigation water quantity, i. e. (a) Recommended level (RL) which is the amount of the water applied to replenish crop evapotranspiration (ET+20% ET) as leaching requirements and (b) farmers level (FL) which is RL+30%RL as excess water.

2.2 Crop rotation: Two crop rotations were applied as follows: Chemical Fertilizers:

2.3 Chemical Fertilizers:

Balanced NPK fertilizers (Table 1) were applied at 4 levels i.e. zero (0), low (L), recommended (M) and high (H). Phosphorus fertilizer was applied pre-planting for all crops, while potassium was applied for all crops before the first irrigation. Nitrogen fertilizer was added at the proper time for each crop.

Cropping season	Year 1	Year 2	Year 3
	Prevailing crop rotation (Rot. I)		
Winter crops	Berseem	Faba bean	Wheat
Summer crops	Maize	Tomato	Sunflower
	Proposed crop rotation (Rot. II)		
Winter crops	Berseem	Faba bean	Wheat
Summer crops	Tomato	Maize	Cow pea
Nile crops	Nile Maize		Sunflower

2.4 Organic manure:

Old fermented organic manure was applied in 2 rates, zero and 71m^3 h^{-1} (31.5 tons/ha) before planting and incorporated into the soil at the beginning of the first and the second cycle of the 3-year crop rotation. The experimental design was split-split block design in 3 replicates with plot size of 70m^2.

2.4 Soil analysis:

Soil surface samples (0-30cm) were collected from each plot individually before planting (0-time) and after the first and second cycle of 3-years crop rotation. The samples were subjected to chemical analysis for the available macronutrients (N, P and K) according to (Jackson, 1973) and micronutrients (Fe, Zn, and Mn) according to (Lindsay Norvell, 1978). Soil organic matter was also determined according to (Walkley and Black, 1934).

2.5 Statistical Analysis:

Average values from the 3-replicates of each treatment were interpreted using the analysis of variance (ANOVA) with separation of means accomplish bed by using LSD at 5%.

2.6 Analysis of organic manure:

The total amount of applied organic manure on the dry basis in the 3-years crop rotation was 31.5 ton/ha. The nutrients content of this organic manure amount were as follows:

Table 1: Fertilizer rates (kg ha^{-1}) of the grown crops.

Crop	Low rate			Medium rate			High rate		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Winter crops									
Wheat	95	24	36	190	48	72	285	72	108
Berseem	24	24	36	48	48	72	72	72	108
Faba bean	36	36	36	72	72	72	108	108	108
Tomato	143	48	57	286	96	114	429	144	171
Summer crops									
Maize	167	18	36	334	36	72	500	54	108
Tomato	167	48	57	334	99	114	500	144	171
Sunflower	60	24	36	120	48	72	180	72	108
Cow pea	36	24	36	72	48	72	108	72	108
Rot. I	552	174	237	1104	348	475	1656	522	713
Rot. II	756	216	310	1512	432	619	2268	648	929

Plant nutrients	N	P	K	Fe	Zn	Mn
			%		$\mu g\ g^{-1}$	
Average concentration	0.52	0.34	1.26	0.22	27.00	68.00
Total amount of nutrients in kg/ha	164.00	108.00	397.00	70.00	0.85	2.14

RESULTS AND DISCUSSIONS

3.1 Effect of crop rotations on soil fertility build up:

Soil fertility status after the first and second cycle of the 3-years crop rotation was evaluated under 2 crop rotations, different levels of balanced NPK, with and without organic manure application and water quantity. Application of the proposed crop rotation showed significant increase in soil N content by about 19% over the prevailing one after the first cycle of the 3 years crop rotation, as more were grown with higher amounts of inorganic NPK (Table 1). On the other hand, minor changes were shown for P,K and micronutrients. After the second cycle, the available soil content of N, P, K and O.M were increased by 7.6%, 26.5%, 9% and 10.6% respectively under the proposed crop rotation over the prevailing one. The higher nutrient contents of the proposed crop rotation may be 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, schilling *et al.*, 1998, Safwat *et al.* 2000). In general, the available soil contents of micronutrients showed lower values after the second cycle compared to the first one and this may be due to the removal amounts by crops during the two crop rotations cycles, as shown in (Table 2).

3.2 Effect of different levels of N,P and K application on soil fertility build up:

The available nitrogen, phosphorus and potassium were significantly increased by increasing N, P and K fertilizer levels over all the other tested factors after the first cycle (Table 3), while either organic matter content or the micronutrients were not significantly affected by increasing the fertilizer levels application. The increase in available N, P and K by the application of low, medium and high fertilizer levels of N P and K over the zero N P K treatment were 18%, 49% and 78% for N residuals, while for P these increases reached 24.0%, 50.7% and 71.7%. As the increases were 14.5%, 25.1% and 31%, respectively after the first cycle, while comparable increased values for the second cycle were 66.9%, 100% and 186% for N residuals, but for residual P these increases were 98%, 188% and 295%, while for K residuals the increases reached to 32%, 59% and 83%, respectively. Moreover, the soil organic matter content was improved by 15.5%, 27.5% and 33.1% respectively by the application of the low, medium and high levels. The soil organic matter content build up was improved after the second cycle, since it was increased by 16.3, 29.3 and 32.2% under low, medium and high application of fertilizer levels over the first cycle of 3-years crop rotation.

In conclusion, the soil organic matter content, available macro and micronutrients were improved after the first and second cycle of 3-years crop rotation compared to the zero-time samples (beginning of the field trial). The available soil contents of macro and micronutrients were decreased after the second cycle of 3-years crop rotation compared to the available soil contents of the first cycle, as shown in (Table 3).

In this respect and under intensive cropping system in the subtropic areas, large amount of plant nutrients are removed by the crops and thus a gradual decline in soil fertility. In a long-term fertilizer treatments, Singh, (1998) in India, Martinovic, (1998) in Yogoslvia, Abd El Hadi, *et al*

Table 2: Effects of different crop rotations on soil fertility build up after two cycles of 3-years crop rotation.

Crop Rotation	O.M	N	P	K	Zn	Fe	Mn
	%			$\mu g\ g^{-1}$			
First cycle							
Prevailing	1.44	39.62a	39.65	477.10	0.86	10.32	12.43
Proposed	1.39	47.14b	38.61	490.35	0.85	10.15	12.37
Sig.L.	ns	s	ns	ns	ns	ns	ns
Second cycle							
Prevailing	1.61	30.08	29.44a	454.44a	1.08	6.21	8.70
Proposed	1.78	32.37	37.25b	495.27b	1.02	6.09	8.01
Sig.L.	ns	ns	s	s	ns	ns	ns

Sig.L. = significance level; s= significant differences; ns= not significant differences

Table 3: Effect of different levels of N, P and K fertilizer application on soil fertility build up after two cycles of 3-year crop rotation.

Fertilizer level	O.M	N	P	K	Zn	Fe	Mn
	%			$\mu g\ g^{-1}$			
				First cycle			
Zero	1.42	31.85a	28.64a	411.25a	0.84	10.21	12.16
Low	1.41	37.57b	35.51b	470.81b	0.88	10.40	12.47
Medium	1.40	47.59c	43.15c	514.63c	0 86	10.15	12.52
High	1.43	56.53d	49.17d	538.18d	0.84	10.18	12.44
				Second cycle			
Zero	1.42	16.57a	13.60a	330.67a	1.00	6.13	8.20
Low	1.64	27.66b	26.90b	436.35b	1.09	6.13	8.47
Meduim	1.81	33.24c	39.22c	526.35c	1.08	6.13	8.33
High	1.89	47.43d	53.65d	606.05d	1.03	6.21	8.42
Zero-time	1.2	29,0	10.5	474	1.0	9.3	12.2
Sig.L.	ns	s	s	s	ns	ns	ns

Sig.L. = significance level; s= significant differences; ns= not significant differences

(2000) in Egypt, indicated that there were 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. Moreover, Schilling *et al,* (1998) mentioned, that the water soluble portion of lizodeposition contains more than 50% of 8 different sugars, 10-40% carboxylic acids and 10-15% amino acids and amides, which increased the availability of P in the soil solution. Kaiser et al, (2000), suggested that in particular organic P-formers can be mobile in soil and enter the hydrosphere.

3.3 Effect of organic manure application on soil fertility build up:

Data presented in (Table 4) showed that after the first cycle of the 3-years crop rotation, the residual available N, P, K and O.M% content were significantly increased by organic manure application, since N, P, K and O.M% increased by 30% 133%, 36% and 34% respectively. Minor changes were obtained for Fe, Zn and Mn contents. After the second cycle of 3-years crop rotation, the soil organic matter content was improved compared to the first cycle, since it was increased by 11.5% and 26% under without and with manure addition respectively. It was found that after second cycle, the soil organic matter content was increased by 51% due to the application of organic manure compared to zero manure treatment.

Similar observations have been earlier recorded, in Rothamsted Research station. Johston, (1997) mentioned that for many annual crops, little residual inorganic N remains in the soil at harvest, when N is added during active growth in the correct amount. Not all of the added N is in the harvest crop, some will be in the soil organic matter and some will have been lost. He also found that even where farmyard manure had been applied for many years most of the P was in the inorganic fraction.

Table 4: Effect of organic manure application on soil fertility build up two- cycles of 3-years crop rotation.

Soil nutrients	First cycle			Second cycle		
	-OM	+OM	Sig.L	-OM	+OM	Sig.L
O.M, %	1.21	1.62	ns	1.35	2.04	ns
N, $\mu g\ g^{-1}$	37.73a	49.03b	s	28.84	33.61	ns
P, $\mu g\ g^{-1}$	23.54a	54.72b	s	27.39a	39.29b	s
K, $\mu g\ g^{-1}$	409.74a	557.70b	s	438.58	511.31	ns
Zn, $\mu g\ g^{-1}$	0.84a	0.87b	s	0.93	1.17	ns
Fe, $\mu g\ g^{-1}$	10.11	10.37	ns	5.64	6.66	ns
Mn, $\mu g\ g^{-1}$	12.29	12.51	ns	7.72	8.99	ns

- OM = without organic manure; +OM = with organic manure
Sig. L = significance level; s= significant differences; ns= not significant differences

The results showed that the retention and release of P was associated with a range of soil components and bonding energies to these constituents. In a long-term trail, Quintern *et al.* (2006), mentioned that the soil organic matter content increased slightly after grass-clover and after the application of farm yard manure, and led to increase contents of extractable K and P in the top soil. In a long-term field trial where animal manure and mineral fertilizers were added, Guggenberger, *et al.*, (2000) stated that most of the active soil organic P is associated with clay size of 0.002 mm, as this fraction is being important in the short-term turnover of the soil P. In another field trials Chater and Mattingly (1980), found that the total P pool in arable soils may be little affected by contrasting fertilization practices. The average content of soil K either under the application of NPK fertilizer levels and under zero manure (409.74 $\mu g\ g^{-1}$) addition was lower than the K- soil content at starting of the experiment (474 $\mu g\ g^{-1}$). It means that K removed by the plants under the intensive cropping system of this long-term field trial was higher than the K-added as fertilizer and the transfer rate from non-exchangeable K to exchangeable K was not enough to keep the concentration at the rate of 0-time. In this respect Johnston and Goulding (1990), mentioned that in the long-term trial in Rothamsted, the increase in total K varied more with clay content than with K- reserves from manure and fertilizer application. The building up of N and P under with and without the addition of organic manure were lower after the second cycle compared to the first one, may be as under the intensive copping system in this field trial, N and P removed by plants were higher than the added N P K fertilizers and organic manure, since that 35% of the N from organic manure was available in the first year of application followed by 12% in the second year and 5% the in 3rd year while the release of P was associated with calcium carbonate as a component fraction of this soil.

3.4 Effect of irrigation water quantity on soil fertility build up.

The obtained results (Table 5) showed that the available N, P and K were slightly improved under the application of the recommended water irrigation regime compared to the farmer level after the first cycle of the 3-years crop rotation. Residual organic matter content was also improved after the second cycle, since it was increased by 20% and 24% under the application of farmer and recommended irrigation level compared to the first cycle.

3.5 Relative contribution effect of tested factors on soil fertility build up

Organic farming system is important, especially in such calcareous soils, because organic manure application improves both soil fertility and soil properties. This was confirmed by studying the RC% of the studied factors for soil fertility parameters (Table 6), since organic manure gave the highest RC% values for N,P and K residuals by 23.1, 75.0 and 56.7% respectively, while it recorded 39.1, 23.5 and 6.0% for Zn, Mn and Fe respectively.

Table 5: Effect of water quantity on soil fertility after two cycles of 3-years crop rotation.

Water level	O.M	N	P	K	Zn	Fe	Mn
	%			$\mu g\ g^{-1}$			
				First cycle			
Farmer	1.40	42.11	38.55	478.62	0.84	10.22	12.49
Recommended	1.37	44.64	39.70	488.76	0.86	10.25	12.31
				Second cycle			
Farmer	1.68	31.26	33.29	470.90	1.05	6.17	8.28
Recommended	1.70	31.19	33.39	478.76	1.05	6.13	8.43
Sig. L	ns	ns	ns	ns	ns	ns	ns

Sig. L. = significance level; s= significant differences; ns= not significant differences

Table 6: Relative contribution (RC%) of affecting factors on macro and micronutrients residual and organic matter content in the soil of Nubaria.

Factors	N	P	K	Zn	Fe	Mu	0.M
Water quantity	-	2.03	-	-	-	-	6.18
Crop rotation	3.34	-	-	-	-	8.46	-
Added O.M	23.13	75.01	56.74	39.15	6.0	23.49	85.92
Added N	66.83	-	-	-	-	-	-
Added P	-	18.58	-	-	-	-	-
Added K	-	-	32.94	1.88	-	-	-
Total	93.30	95.62	89.68	41.03	6.0	31.95	92.15

Moreover, organic manure application had the highest RC (about 86%) for soil organic matter content. On the other hand, application of N, P and K fertilizers showed RC only for the corresponding nutrient by 66.8, 18.6 and 32.9% for N,P and K respectively. Meanwhile water quantity, showed RC 2.03% for P and 6.18% for O.M, while crop rotation showed RC of 3.34% for N and 8.46% for Mn.

CONCLUSIONS

1. After the two cycles of 3-years crop rotation, the available residual of N, P, K and organic matter content were significantly increased under the three fertilizer levels especially the medium and high levels which showed greater increments.
2. Application of organic manure also improved soil content of available N, P, K, O.M, Fe, Zn and Mn after the second cycle of 3-years crop rotation.
3. The proposed crop rotation showed higher values of residual N, P, K and soil organic matter content, while values of micronutrients showed minor changes
4. Fe and Mn residuals showed lower values after the second cycle of 3-years crop rotation compared to the first one may be due to the removal by crops during the 3- year crop rotation.

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الملخص العربى

استدامة حالة خصوبة التربة بعد دورتين محصوليتين كل منهما تعاقب محصولى لثلاث سنوات فى الأراضى الجيرية بمصر

عبدالله همام عبد الهادى[١]، رشاد أبوالعينين رشاد[٢] ، أحمد محمد عوض[١] ، جمال محمد الشبينى[١] ، محمد السيد مرسى[١]

[١]معهد بحوث الاراضى و المياه و البيئة ، مركز البحوث الزراعية ، الجيزة ــ مصر

[٢]معهد بحوث المحاصيل الحقلية ، مركز البحوث الزراعية ، الجيزة ــ مصر

اقيمت تجربة طويلة الأمد تحت نظام الرى السطحى بأقليم غرب دلتا النيل (محطة البحوث الزراعية بالنوبارية) والتى تمثل مساحة كبيرة من الأراضى الرملية والرملية اللومية الجيرية بمحتوى من كربونات الكالسيوم يتراوح بين ٢٠-٤٠% . اقيمت الدراسة فى المواسم الزراعية ١٩٩٦/٩٧ حتى ٢٠٠٢ تحت ظروف إدارة الموارد المختلفة مثل: ٤ مستويات من التسميد المتزن بعناصر النيتروجين (N) والفوسفور (P) والبوتاسيوم (K) (بدون ، منخفض ، متوسط ، مرتفع) ؛ مع إضافة وعدم إضافة السماد العضوى ؛ كذلك مستويان من كمية مياه الرى (معاملة رى موصى بها ، معاملة رى المزارع) ؛ وأخيرًا اثنان من التعاقب المحصولى (مخططة ، عشوائية).

أخذت عينات أرض عند بداية التجربة (زمن صفر) وكررت مرتين بعد نهاية أول وثانى دورة محصولية ، كل منهم ٣ سنوات من التعاقب المحصولى ، حيث جمعت العينات بغرض تتبع تركيز العناصر المغذية الكبرى (K, P, N) والصغرى (Mn, Zn, Fe) ومحتوى المادة العضوية (OM%) ، وقد أوضحت النتائج المتحصل عليها مايلى:

١. كان تركيز المتبقى المتيسر من عناصر NPK قد زاد معنوياً بزيادة معدل إضافة هذه العناصر بعد الدورة المحصولية الاولى والثانية ، بينما لم تتأثر عناصر الحديد والزنك والمنجنيز معنوياً.

٢. أيضاً حسنت إضافة الاسمدة العضوية محتوى الأرض من كل العناصر الكبرى والصغرى والمادة العضوية بعد الدورة المحصولية الثانية للتعاقب المحصولى لـ ٣ سنوات ، وعموماً فإن إضافة السماد العضوى زادت من محتوى الأرض من عناصر KPN والمادة العضوية بنسبة ١٦,٥% ، ٤٣,٥% ، ١٦,٥% ، ٥١,٠% على الترتيب . كذلك زاد محتوى الأرض من عناصر Mn, Zn, Fe بنسبة ١٨,٠% ، ٢٦,٠% ، ١٦,٥% على الترتيب بالمقارنة بمعاملة عدم إضافة السماد العضوى.

٣. أظهرت الدورة المحصولية المخططة زيادة معنوية فى النيتروجين المتبقى فقط بالمقارنة بالدورة المحصولية العشوائية، بينما لم يتأثر معنوياً الفوسفور والبوتاسيوم المتبقيان بعد هذه الدورة المحصولية الاولى. بينما بعد الدورة المحصولية الثانية حدثت زيادة معنوية فى الفوسفور والبوتاسيوم المتبقيان تحت الدورة المحصولية المخططة ، ولكن محتوى المادة العضوية والنتروجين لم يتحسنا بشكل ملموس.

٤. اظهرت نتائج الحديد والمنجنيز المتبقيان قيم منخفضة فى الدورة المحصولية الثانية بالمقارنة بالدورة المحصولية الأولى ، وقد يكون هذا راجعًا إلى الكميات الممتصة بواسطة المحاصيل خلال الدورتين المحصوليتين التى أستمرت كل منهما ٣ سنوات من التعاقب المحصولى.

٥. حدث تحسن فى محتوى الأرض من العناصر الكبرى (KPN) المتيسرة تحت ظروف الرى بكميات المياه الموصى بها بالمقارنة بمعاملة المزارع بعد كلا الدورتين المحصوليتين الاولى والثانية.

٦. أظهرت الأسمدة العضوية المضافة مساهمة نسبية كبيرة (RC%) فى زياد نسبة المادة العضوية بقيمة ٨٥,٩% و للعناصر الكبرى KPN بقيمة ٢٣,١% ، ٧٥,٠% ، ٥٦,٧% على الترتيب . بينما سجلت قيم RC% ٣٩,١% ، ٢٥,٥ ، ٦,٠ ، لكل من الزنك و المنجنيز والحديد على الترتيب. قد كان لإضافة أسمدة النترجين والفوسفور والبوتاسيوم مساهمة نسبية فقط للعنصر السمادى المستهدف بقيم ٦٦,٨% ، ١٨,٦ % ، ٣٢,٩% لعناصر KPN على الترتيب . بينما أظهرت كميات مياه الرى قيمة مساهم نسبية ٢,٣% للفوسفور و٦,٢% لمحتوى المادة العضوية ، فى حين أن الدورة المحصولية أظهرت مساهمة نسبية بقيمة ٣,٣٤% للنيتروجين و ٨,٥% للمنجنيز.