SUSTAINABILITY OF SOIL FERTILITY STATUS AFTER 3-YEAR CROP ROTATION IN SANDY SOILS IN EGYPT

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Abstract

A three years field experimsent was carried out at El-Bustan area - west Nile Delta which represents a vast area of the newly reclaimed sandy soils (98.5% sand), poor in organic matter, both macro- and micro-nutrients as well as water holding capacity.

The main objective of this experiment was to promote sustainability and fertility build up in sandy soils .

A split plot design with three factors in three replications was followed.

a) The first (main plots) is the water quantity at two levels:
Required irrigation water (R) = Evapotranspirtion (ETc) + 20% ETc and Farmer (f) = R + 30% of R, using sprinkler irrigation system.
b) The second factor (split plots) is the crop rotation: the prevailing rotation (Rot.I) and intensive (proposed) rotation (Rot.П). In (Rot.I) : wheat - groundnut were grown in the first and the second years while berseem - groundnut in the 3 third year. Crops grown in (Rot.П) were berseem-groundnut, wheat-sesame and pea-sunflower- maize in the first, second and third year, respectively.
c) The third factor (split- split plots) is balanced N, P and K levels, (low, medium and high) with and without organic manure.

Representive soil samples were taken at the starting of the experiment (1996) and after the three years (1999) to follow up changes in organic matter content (O.M.), and macro-& micro-nutrients. Samples which were taken at the start indicate that average organic matter content was 0.25%; and 9.25, 3, 114, 2.05, 1.24 and 0.32 ppm for available N, P, K, Fe, Mn and Zn, respectively. The most important findings are:

- Soil organic matter content was relatively increased by organic manure application .
- Organic manure induced marked increases in the available soil P by about 46.3% over zero- organic manure, 20.07% and 5.96% for available K and available N respectively.
- Values of available Fe, Mn and Zn in the soil were increased by organic manure application.
- Crop rotation and water quantity had no remarkable effects on the soil fertility build up.

- The available residuals of the applied N, P and K increased by increasing the applied N, P and K levels.

INTRODUCTION

Egypt faces a growing imbalance between agriculture production and population increase. Population increased from 20 million in the year 1950 to 68 million in the year 2000 while the cultivated area increased from 2.20 to 3.25 million hectares for such period showing that the ratio of these parmeters is about 5:1. Beside vertical expansion in the old land (alluvial soils), horizontal expansion should be taken into consideration to achieve a balance between population and agricultural production. Improving fertility of the new reclaimed sandy soils could share in this respect. About one million hectare of sandy desert soils close to Nile Delta and Nile Valley could be added to the cultivaed area in Egypt (Nagmoush and EL Kased,1992). Desert soi1s are deficient in organic matter (OM) and have a very limited capacity to supply most of the plant nutrients. Build up of OM is essential for improving such soils through enhanced plant nutrients availability, (Amer, 1988).

Khadr *et al.* (1986) and Awad (1994) reported that organic amendments increased extractability of Zn, Mn and Fe in addition to macro nutrients (NPK). Follet *et al* (1987), Kern and Johanson (1993) showed that OM has a large influence on long term sustainability of soil and it is important for plant nutrition, soil structure and water holding capacity. The use of NPK fertilizers significantly increased the content of readily available forms of P and K (directly resulting from PK fertilizers) as well as iron and manganese (indirectly owing to changed chemical properties), while application of fertilizers did not affect the content of readily available forms of B, Zn and Cu. (Ljubisa *et al.*, 1998 and Singh, 1998). Abd- El-Hadi *et al.* (2000) found from a long term field trial in Egypt after three years crop rotation that soil fertility in terms of available soil contents of N, P and K was generally improved by application of either required or high levels of NPK fertilizers. Pieri and O'connell (1998) reported that water and organic materials are one of the components of sustainable land management and soil fertility improvement Abd-EI-Hadi *et.al.* (l986) and Bauer and Black (1994) reported that soil OM has effects on soil chemical, physical and biological properties that in turn contribute to improve crop yield. Gaafar (1988) pointed out that the main function of

OM in sandy soils is increasing water holding capacity, helps the availability of water or even the nutrient solution around the root system. Delibacak *et al.* (2000) showed that addition of different levels of farmyard manure increased total soluble salts, OM, aggregation percentage. Miah (2000) found from fie1d experiments and on farm trails, marked increases in organic C content of the soil after four crop cycles due to the use of cow dung and incorporation of dhainba as green manure.

E1-Bustan area represents a fast area of sandy soi1s such area was selected to carry out a semi long term field trial to study the effect of mineral and organic manure, water irrigation level and two crop rotations on available nutrients in such sandy soils.

MATERIALS AND METHODS

A long term field exprimenat is conducted in El-Bustan region (A sandy soil west Nile Delta Egypt); it started in l996/1997 growing season.

The experimental design is split split with three replications; plot area is 7 X 9=63m^2

Treatments are:

- Irrigation water quantity: (2 levels)- Required and farmer levels in the main plots.

Required (irrigation water level) (R) = ETc + 20% (El-Gibali and Badawi 1978)

and Farmer (irrigation water level) =R + 30% R.

- Rotations: Two crop rotations, Prevailed and proposed rotations in the split plots.

Crop rotations:

Prevailed (Rot.I)	Proposed (Rot. Π)
Wheat Ground nut	Berseem Ground nut
Wheat Ground nut	Wheat Sesame
Berseem Ground nut	Pea Sunflower Maize

- Fetilizers: (in the split plots) Three levels of NPK (Low - Medium - High) with and without organic manure, (3 levels of NPK X 2 organic manure levels) = 6. List of applied NPK levels are shown in Table (1). Organic manure are used at the rate of 72 m^3 /ha yearly.

Represntative soil samples were taken after preparation of the experiment and before application of any fertilizer at zero time. After 3 years of crop rotation, soil samples from each plot were taken again and all samples were subjected for chemical analysis according to Jackson (l974) and Lindsay and Norvell (1978). Analysis of zero time samples show that values of OM and available nitrogen are low, their average values were 0.25% and 9.25 ppm, respectively. Average available phosphorus value was also low (3 ppm). Average available K value was 114 ppm. Average available micro-nutrients Fe, Mn and Zn were 2.45, 1.24 and 0.63 ppm respectively (values < 2.5 ppm Fe, < 1.2 ppm Mn and < 0.6 ppm Zn are deficient; Lindsay and Norvell 1978).

The value of pH was in the alkaline side (8.0 - 8.2). Electrical conductivity for soil water extracts (1:5 soil:water) was 0.12 mmhos /cm/25 ^{o}C. $CaCO_3$ was 5.2%. Particle size distribution was 98, 1.3 and 0.7% for sand, silt and clay, respectively. Water table depth was at 220 cm. All mentioned data show that this soil has on open profile. Analysis of soil samples after 3 years crop rotation are shown in tables 2 to 8.Analysis of the applied organic manure (cattle manure) is shown below:

Nutrients	N	P	K	Fe	Zn	Me
	%			Ppm		
Average analysis	0.58	0.30	1.45	2551	30	167

RESULTS AND DISCUSSION

A- Organic matter:

Data presented in Table (2) show that after 3-year application of organic manure (cattle manure), soil OM, in average, increased by 32%. The soil OM content was not affected by increasing the rate of NPK fertilizers. Rot. I gave generally higher values than Rot. II for the required water level. In spite of the effect of organic manure, OM content was still very low showing that the soil needs a long time to has

normal content. In this respect, Awad,(1994) and Safwat *et al.*(2000) pointed out that application of organic manure increased soil OM content.

B- Available nitrogen:

Figures of available N in the soil after the 3-year crop rotation are presented in Table 3 showing that they were very low at the zero time (8.5 - 10 ppm). Application of NPK fertilizers increased gradually available N as the rate increased. Application of organic manure with NPK gave higher values of available N than application of NPK alone. Values of available N for the required and famer water levels were similar in the case of organic manure application treatment with NPK while mean values for the non organic manure treatment were higher in the required water level. This result could be attributed to leaching of nutrients in the case of application of more irrigation water (farmer level). Average values of Rot.I.and Rot.Π were similar. In spite of increasing available N after the 3 years crop rotations these values are still low. In Rothamested Research Station, Johnston (1997) mentioned that for many annual crops little residual inorganic N remain in the soil when N is added during active growth in the correct time.

C-Available phosphorus:

Mean values of available P content in the soil after the 3-year crop rotation (Table 4) significantly increased as the rate of NPK fertilizers increased. Higher values were obtained in the case of organic manure application with NPK fertilizers. However, the available soil P content was neither affected by crop rotation nor by water quantity. It is worth to mention that aIthough the available soil P content was improved after 3- year crop rotation, it is still insufficient for growing many crops since it falls in the low to medium range (low up to 5 ppm, medium 5 - 10 ppm, Jackson 1974). In this concern, Chater and Mattingly (1980), found that the total P pool in arable soils may be little affected by contrasting fertilization practices.

D-Available potassium:

Figures of available K obtained after the 3-year crop rotation (Table 5) indicated that increasing the level of applied NPK fertilizers significantly increased available K content of the soil. Application of organic manure with NPK fertilizers gave higher values than those obtained from NPK only. These results could be attributed to the relatively low clay and O.M. content of such soil. Application of the organic manure added relatively marked amounts of nutrients to the soil specially K as shown in the analysis of the applied manure. The tested irrigation water levels and crop rotations gave no marked effect on soil content of available K. It is worth to mention that values of available K at zero time were higher than those after 3 years crop rotations. This could be attributed to leaching of K deep in the soil profile, since the soil is poor in clay and O.M. in addition to depletion by crops.

E-Available micro-nutrients:

Iron (Fe): Average values of available Fe content (Table 6) clearly increased as a result of NPK application over zero time values. Increasing NPK rates gave higher values of available Fe content. Application of organic manure with NPK fertilizers gave the highest values. The intensive rotation (Rot. Π) gave higher available Fe content. This could be due to more applied NPK and bigger root system which resulted in more root secretion and consequently more release of available Fe. The required irrigation water level gave higher values than the higher irrigation water level (farmer level).

Manganese (Mn): Application of NPK gave higher available Mn values (Table 7) compared with zero time. Rates of NPK gave similar values. Application of organic manure in addition to NPK resulted in higher available Mn content values.Rotations (Rot. I and Rot. II) gave simliar results . Average value of farmer water irrigation level was higher than the required level.

zinc (Zn): Application of NPK fertilizers clearly increased available Zn content (Table 8) as compared with zero time. Rates of NPK insignificantly affected available Zn content. Required water level, Rot. II and application of organic manure gave little increase over famer level, Rot. I and organic manure, respectively.

CONCLUSION

Application of NPK fertilizers and organic manure to sandy soils under semi-arid conditions improved soil fertility slowly since tested parameters after 3-year crop rotation were as follows:

- O.M. content of the soil, as a result of organic manure and NPK becomes 0.37% only in spite of being increased by about 40%.
- Application of NPK rates increased available N content from 12.7 to 16.9 ppm compared to the average of zero time which was 9.25 ppm, showing that available N content is still deficient.
- Average available P content resulted from the medium rate of NPK and that received organic manure were 5.29 ppm and 6.38 ppm, respectively, where organic manure was used with NPK, compared with an average of 3 ppm for zero time indicating that available P is still low.
- The highest average value of available K (49.9 ppm) is obtained by the highest NPK rate after the 3-year crop rotation.
- Soil content of available micro-nutrients increased by application of NPK after the 3-year crop ratation where Fe increased from 2.04 to about 7.0 ppm. Organic manure gave generally higher values. Available Mn and Zn gave the same trend.
- Generally, under semi arid conditions the application af NPK and organic manure needs to be continuous.

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استدامة خصوبة التربة تحت الدورة الثلاثية بالأراضي الرملية في مصر

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أقيمت تجربة حقلية مستديمة فى منطقة البستان (غرب الدلتا) التى تمثل مساحة شاسعة من الأراضى الرملية حديثة الاستصلاح (٩٨,٥ % رمل) وهى تعتبر فقيرة في المادة العضوية وكل من العناصر المغذية الكبرى والصغرى علاوة على ضعف قدرتها على الاحتفاظ بمياه الرى . والهدف الرئيسى من هذه التجربة هو العمل على بناء خصوبة التربة .

والتصميم الإحصائى فى هذه التجربة هو القطع المنشفة مرتين حيث أشتملت على ثلاث عوامل فى ثلاثة مكررات والعوامل المدروسة هى :

أ – القطع الرئيسية عبارة عن كمية مياه الرى بمستويين المستوى الأول هو إحتياجات الرى والثانى عبارة عن المستوى الذى يستخدمه الفلاح (٣٠ % زيادة عن المستوى الأول) وذلك بإستخدام نظام الرى بالرش .

ب – القطع المنشفة الأولى وتشمل الدورة الزراعية : الدورة الشائعة بالمنطقة والدورة المقترحة . والدورة الشائعة هى: قمح – فول سودانى فى السنة الاولىوالثانية والبرسيم والفول السودانى فى السنة الثالثة. والدورة المقترحة هى : برسيم – فول سودانى ، قمح – سمسم ، بسلة – عباد شمس – ذرة شامية وذلك فى السنوات الأولى والثانية والثالثة على الترتيب .

ج – العامل الثالث : فى القطع المنشفة الثانية وهو إستخدام معدلات متزنة من الأزوت والفوسفور والبوتاسيوم بثلاث مستويات (منخفض – موصى به – عالى) فى وجود وعدم وجود السماد العضوى .

تم أخذ عينات تربة ممثلة لأرض التجربة عند بداية التجربة (١٩٩٦) وعقب إنتهاء دورة كاملة (١٩٩٩) وذلك لمتابعة التغير فى محتوى التربة من المادة العضوية والعناصر الغذائية الكبرى والصغرى .

أشارت نتائج تحليل العينات فى بداية التجربة أن متوسط محتوى المادة العضوية كان ٠,٢٥ % وكانت قيم الأزوت والفوسفور والبوتاسيوم الميسرة هى ٩,٢٥ ، ٣ ، ١١٤ جزء / مليون بينما كانت ٢,٠٥ ، ١,٢٤ ، ٠,٣٢ جزء / مليون بالنسبة للحديد والمنجنيز والزنك على التوالى .

وأهم النتائج المتحصل عليها بعد ثلاث سنوات هى :

- زيادة محتوى التربة من الأزوت والبوتاسيوم والفوسفور الميسرين بزيادة معدل التسميد لهذه العناصر .
- أدى استخدام السماد العضوى إلى زيادة ملموسة فى محتوى التربة من الفوسفور الميسر بحوالى ٤٦,٣ % عن تلك الغير مسمدة بالسماد العضوى، وكذلك بنسبة ٢٠,٠٧ % ، ٥,٩٦ % للبوتاسيوم والنيتروجين على التوالى .
- زيادة طفيفة فى محتوى التربة من المادة العضوية باستخدام السماد العضوى .
- الدورة الزراعية وكمية مياه الرى لم يظهر لهما تأثير واضح على خصوبة التربة .
- زيادة مستوى الحديد والمنجنيز والزنك الميسر بالتربة وذلك بإستخدام السماد العضوى .

Table 1. Mineral fertitizer rates (Kg/ha) for field crops of El - Bustan sandy soil.

Crops	Fertilizer levels								
	Low			Medium			High		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Winter crops									
wheat	120	24	48	240	48	96	360	72	144
Berseem	48	36	48	96	72	96	144	10	144
Pea	60	36	48	120	72	96	180	108	144
Summer crops									
Sunflower	60	36	48	120	72	96	180	8	144
Sesame	60	36	48	120	72	96	180	108	144
Ground nut	48	36	48	96	72	96	144	108	144
Maize	132	36	48	264	72	96	396	108	144
Rotation I	432	192	288	864	384	576	1296	576	864
Rotation II	528	240	336	1128	480	672	1692	720	1008

Table 2. Effect of NPK fertilizer rates, organic manure and water quantity, after 3 years crop rotation, on soil organic matter content (%) in El - Bustan sandy soil.

Rotation	Fertlizer level	Zero manure			+ manure		
		Water quantity			Water quantity		
		Recomm.	Farmer	Mean	Recomm.	Farmer	Mean
Zero time		0.21	0.29	0.25	0.21	0.29	0.25
Rotation I	Low	0.29	0.23	0.26	0.41	0.35	0.38
	Medium	0.29	0.24	0.27	0.38	0.36	0.37
	High	0.32	0.24	0.28	0.24	0.34	0.38
Mean (Rot. X Manure)		0.30	0.24	0.27	0.40	0.35	0.38
Rotation II	Low	0.24	0.30	0.27	0.36	0.39	0.38
	Medium	0.23	0.27	0.25	0.36	0.39	0.36
	High	0.24	0.27	0.26	0.36	0.40	0.38
Mean (Rot. X Manure)		0.24	0.28	0.26	0.36	0.40	0.38

Rotation average = Rotation I = 0.33, Rotation II = 0.33
Water quantity average = Required = 0.33, Farmer = 0.33
Manure average = Zero manuure = 0.27a + manure = 0.38b
Fertilizer average Low : 0.33, medium : 0.32 and high : 0.33
L. S. D. 5 % = 0.06
The averages which have the same letter or on letter means that there is no significant difference while different letters means that there is significant difference between the tow averages.

Table 3. Effect of NPK fertilizer rates, organic manure and water quantity, after 3 years crop rotation, on soil N content (ppm) in El - Bustan sandy soil.

Rotation	Fertlizer level	Zero manure			+ manure		
		Water quantity			Water quantity		
		Recomm.	Farmer	Mean	Recomm.	Farmer	Mean
Zero time		10.0	8.5	9.25	10.00	8.50	9.25
Rotation I	Low	13.0	12.0	12.50	12.10	13.80	12.95
	Medium	13.9	12.9	13.40	14.80	13.80	14.30
	High	17.0	16.7	16.85	18.80	16.60	17.70
Mean (Rot. X Manure)		14.6	13.7	14.15	15.20	14.70	14.95
Rotation II	Low	13.1	11.7	12.40	13.50	12.20	12.70
	Medium	13.1	13.8	13.45	14.20	13.80	14.00
	High	16.3	14.9	15.60	14.40	17.70	17.55
Mean (Rot. X Manure)		14.4	13.7	14.05	15.10	14.70	14.90

Rotation average = Rotation I = 14.55, Rotation II =14.47
Water quantity average = Required = 14.20, Farmer = 14.8
Manure average = Zero manuure = 14.09 + manure = 14.93
Fertilizer average Low : 12.68a, medium : 13.80b and high : 16.93c
L.S.D. 5% = 0.75
The averages which have the same letter or on letter means that there is no significant difference while different letters means that there is significant difference between the tow averages

Table 4. Effect of NPK fertilizer rates, organic manure and water quantity, after 3 years crop rotation, on soil P content (ppm) in El - Bustan sandy soil.

Rotation	Fertlizer level	Zero manure			+ manure		
		Water quantity			Water quantity		
		Recomm.	Farmer	Mean	Recomm.	Farmer	Mean
Zero time		3.80	2.20	3.00	3.80	2.20	3.00
Rotation I	Low	3.61	2.59	3.10	5.04	5.51	5.28
	Medium	4.34	3.87	4.10	6.09	6.27	6.18
	High	5.68	4.80	5.24	8.42	6.87	7.66
Mean (Rot. X Manure)		4.54	3.75	4.15	6.52	6.22	6.37
Rotation II	Low	3.37	4.26	3.82	3.60	5.70	4.65
	Medium	4.84	4.71	4.78	4.90	7.22	6.06
	High	6.38	6.34	6.36	8.25	8.80	8.53
Mean (Rot. X Manure)		4.70	4.43	4.57	6.05	6.73	6.39

Rotation average = Rotation I = 5.26, Rotation II =5.48

Water quantity average = Required = 5.45, Farmer = 5.28

Manure average = Zero manuure = 4.36a + manure = 6.38b

Fertilizer average Low : 4.22a, medium : 5.29b and high : 6.95c

L.S.D. 5% = 1.13

L.S.D. 5% = 0.94

The averages which have the same letter or on letter means that there is no significant difference while different letters means that there is significant difference between the tow averages

Table 5. Effect of NPK fertilizer rates, organic manure and water quantity, after 3 years crop rotation, on soil K content (ppm) in El - Bustan sandy soil.

Rotation	Fertlizer level	Zero manure			+ manure		
		Water quantity			Water quantity		
		Recomm.	Farmer	Mean	Recomm	Farmer.	Mean
Zero time		114.00	114.00	114.00	114.00	114.00	114.00
Rotation I	Low	35.30	37.50	36.40	42.50	45.00	43.80
	Medium	41.40	40.30	40.90	48.10	51.70	49.90
	High	46.40	43.90	45.20	53.60	56.40	55.00
Mean (Rot. X Manure)		41.00	40.60	40.80	48.10	51.70	49.90
Rotation II	Low	36.40	34.20	35.30	37.50	42.20	39.90
	Medium	38.30	41.40	39.90	41.40	47.50	44.50
	High	45.30	46.70	46.00	48.90	56.10	52.50
Mean (Rot. X Manure)		40.00	40.80	40.40	45.30	49.80	47.60

Rotation average = Rotation I = 45.35, Rotation II = 44.00

Water quantity average = Required = 43.60, Farmer = 45.70

Manure average = Zero manuure = 40.60a + manure = 48.75b

Fertilizer average Low : 38.83a, medium : 43.77b and high : 49.90c

L.S.D. 5% = 1.18

L.S.D. 5% = 3.81

The averages which have the same letter or on letter means that there is no significant difference while different letters means that there is significant difference between the tow averages

Table 6. Effect of NPK fertilizer rates, organic manure and water quantity, after 3 years crop rotation, on soil content of availble Fe (ppm) in El - Bustan sandy soil.

Rotation	Fertlizer level	Zero manure			+ manure		
		Water quantity			Water quantity		
		Recomm.	Farmer	Mean	Recomm	Farmer.	Mean
Zero time		2.18			1.90		
Rotation I	Low	6.11	5.04	5.58	6.95	5.34	6.15
	Medium	6.72	5.22	5.97	8.44	6.17	7.31
	High	6.91	5.47	6.19	6.99	5.74	6.37
Mean (Rot. X Manure)		6.58	5.24	5.91	7.46	5.75	6.61
Rotation II	Low	7.29	6.47	6.88	8.99	6.12	7.56
	Medium	6.63	6.23	6.43	7.20	7.08	7.14
	High	8.81	6.99	7.90	8.13	8.02	8.08
Mean (Rot. X Manure)		7.08	5.90	6.74	7.78	6.41	7.10

Rotation average = Rotation I = 6.26, Rotation II = 6.92
Water quantity average = Required = 7.32b, Farmer = 5.83a
L.S.D. 5% = 1.02
Manure average = Zero manuure = 6.33, + manure = 6.86
Fertilizer average Low :6.54a, medium : 6.72ab and high : 7.14b
L.S.D. 5% = 0.47
The averages which have the same letter or on letter means that there is no significant difference while different letters means that there is significant difference between the tow averages

Table 7. Effect of NPK fertilizer rates, organic manure and water quantity, after 3 years crop rotation, on soil content of availble Mn (ppm) in El - Bustan sandy soil.

Rotation	Fertlizer level	Zero manure			+ manure		
		Water quantity			Water quantity		
		Recomm.	Farmer	Mean	Recomm.	Farmer	Mean
Zero time		1.47			1.00		
Rotation I	Low	2.87	3.25	3.06	3.36	4.11	3.74
	Medium	2.77	3.17	2.97	3.91	3.56	3.74
	High	3.18	3.25	3.22	3.46	3.81	3.64
Mean (Rot. X Manure)		2.94	3.22	3.08	3.58	3.83	3.71
Rotation II	Low	3.02	3.49	3.26	3.29	4.24	3.77
	Medium	2.79	3.74	3.27	3.20	4.05	3.63
	High	2.85	3.65	3.25	3.23	3.81	3.52
Mean (Rot. X Manure)		2.91	3.43	3.17	3.41	3.93	3.67

Rotation average = Rotation I = 3.40, Rotation II = 3.42
Water quantity average = Required = 3.21, Farmer = 3.60
Manure average = Zero manuure = 3.13a, + manure = 3.69b
Fertilizer average Low : 3.46, medium : 3.40 and high : 3.41
L.S.D. 5% = 0.32
The averages which have the same letter or on letter means that there is no significant difference while different letters means that there is significant difference between the tow averages

Table 8 Effect of NPK fertilizer rates, organic manure and water quantity, after 3 years crop rotation, on soil content of availble Mn (ppm) in El - Bustan sandy soil.

Rotation	Fertlizer level	Zero manur			+ manure		
		Water quantity			Water quantity		
		Recomm.	Farmer	Mean	Recomm.	Farmer	Mean
Zero time		0.40			0.25		
Rotation I	Low	1.00	1.08	1.04	1.13	0.87	1.00
	Medium	1.01	0.72	0.87	1.13	0.96	1.05
	High	1.09	0.76	0.93	1.15	0.89	1.02
Mean (Rot. X Manure)		1.03	0.85	0.94	1.14	0.91	1.03
Rotation II	Low	1.04	0.99	1.02	1.21	1.12	1.17
	Medium	0.83	1.20	1.02	0.94	1.08	1.01
	High	0.85	1.15	1.05	1.03	0.98	1.01
Mean (Rot. X Manure)		0.94	1.11	1.03	1.10	0.98	1.04

Rotation average = Rotation I = 0.99, Rotation II = 1.04
Rotation average = Rotation I = 0.99, Rotation II = 1.05
Rotation average = Rotation I = 0.99, Rotation II = 1.06
Rotation average = Rotation I = 0.99, Rotation II = 1.07