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EVALUATION OF SEWAGE SLUDGE AS NATURAL SOIL CONDITIONER UNDER SALINE IRRIGATION WATER

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A filed experiment was conducted at Ras Sudr experimental station to find out the effect of application rate and method of sewage sludge on calcareous soil properties and wheat yield under saline irrigation water. Two rates (10 and 20 ton/fed) of sewage sludge applied with two methods; surface and subsurface (0-10cm) and (10-20cm), respectively.

The results indicated that increasing application rate of sewage sludge increased soil E.C values, O.M and available N, P, K, F, Mn, and Zn. The rate of increment differed from one nutrient to another, however the highest value of each nutrient were found with the higher application rate of sludge.

Results showed that application of sewage sludge increased water stable aggregates. Whereas the Aggregation Index (AI), structure coefficient (SC) and Hydraulic conductivity (K) increased with increasing application rate. In contrast the bulk density was decreased.

The dry matter yields of wheat were significantly increased depending upon the rate / or the method of sewage sludge application under saline irrigation water. Mixing the highest rate (20 ton / fed) of sludge with the surface of layer (0-10cm) calcareous soil was the best treatment in this respect. This is reflected on significant increases in the of soil properties and macro, micro nutrients concentrations of grains and straw. Therefore, it is good enough to mix the sludge with the surface layer of 0-10 cm of calcareous soil to ensure better distribution of the sludge manure and to obtain high quantity and quality of the grown plants, when using low quality water in irrigation.

Keywords: saline water, sewage sludge, calcareous soils and wheat plant

The use of sewage sludge as soil conditioner has been a worldwide agricultural practice for many years, it effectively disposes a waste product while recycling valuable nutrients into the soil-plant ecosystem (Warman, 1986).

Sewage sludge application to the soil has direct or indirect effects on soil quality . Many characteristics of sewage sludge among those proposed to be included as basic indicators of soil quality, e.g., total organic C and N content, pH, electrical conductivity and nutrients such as potassium and phosphorus (Doran and Parkin, 1994).

Cunningham *et al.* (1975) reported that sludge addition to sandy loam soil at rates from 63 to 502 metric ton /ha had caused reduction in soil pH, electrical conductivity, in 1:2 soils/ water ratio, was highly increased from 1.3 ds/m for the control to 17ds/m after addition of 502 ton/ha.

Therefore, considering the control of soil erosion as a priority issue in rehabilitating degraded lands, it is interesting to examine how the application of organic amendments may modify soil aggregation and its structural stability. Epstein (1975) reported that sewage (at application rates of 5-10% by weight) initially increased aggregate stability and hydraulic conductivity then declined. Clapp *et al.* (1986) evaluated the results of 23 published studies and concluded that sludge application reduced bulk density (Pδ), and increased total porosity. They also attributed the observed effects to organic matter additions. Logan *et al.* (1996) found that a one-time application of 25% by weight of digested sewage sludge improved soil physical properties as measured by pδ porosity, and soil aggregate stability.

Sludge contains many essential nutrients for plant growth including N, P, K, Fe, Cu, Zn and Mn (Chaney,1973). Although such materials are efficient under good quality water condition, information under irrigation with poor quality water is still lacking. The present investigation was therefore, undertaken to investigate the effect of rate and method of sewage sludge application on calcareous soil properties and wheat yield under saline irrigation water.

MATERIALS AND METHODS

A field experiment was carried out at Ras Sudr experimental station, south Sinai, to study the effect of rate and method of sewage sludge application under saline irrigation water on calcareous soil properties and its productivity. The main characteristics of the experiment soil, saline irrigation well water and sewage sludge are given in Tables(1-3).

The experiment was layed out in a split- plot design with four replicates. Two applications methods were occupied main plots, the first method was mixed with surface (S) soil layer (0-10cm) and the second one was mixed with the sub-surface (SU) soil layer (10-20cm depth). Two rates of sewage sludge were applied for each method(namely 10 and 20 ton /fed) occupied sub plots. Buffer strips 1.5m wide was leaved to minimize the horizontal water seepage. The size of each plot was 9 m^2 (3m × 3m). The plots were flooded and left for four weeks (incubation period),then the plots were fertilized with superphosphate (15.5%) at the rate of 22.5 Kg P_2O_5 / fed added before planting . Ammonium nitrate (33.5%) at the rate of 67 kg N/fed applied at three equal doses (at 15, 30 and 60 days from planting) and potassium sulphate (48%) at the rate of 48 kg K_2O/ fed was added with the first dose of N fertilization.

Wheat seeds (Triticum aestivum L.) Sakha 8 at the rate of 60Kg/ fed, sown in November 2000. The irrigation was immediately took place after sowing using highly saline well water of 8.2 dsm $^{-1}$ (Table 2). Wheat was harvested at the maturity in April 2001 and the biological yield i.e. grains and straw were recorded and statistically analyzed (Snedecor and Cochran, 1980) Also, the N, P, K, Fe Mn and Zn content of grains and straw were determined by Chapman and Pratt (1961). Soil samples were taken after harvesting from 0-10cm and 10-20cm depth for the determination of soil chemical and physical properties. Such methods were carried out according to Richards (1954) and Page *et al.* (1982).

TABLE (1). Initial soil properties of the experiment site.

Soil Depths (cm) / properties	0-10	10-20
pH *	7.72	7.18
EC* dS m^{-1}	1.41	1.97
O.M%	1.03	0.53
Sand %	75.25	82.00
Silt %	11.43	10.11
Clay %	13.32	7.89
Soil texture	Sandy loam	Sandy loam
Available P ($mgkg^{-1}$)	6.52	4.10
Exchangeable K ($mgkg^{-1}$)	109.2	66.3
Total N %	0.020	0.010
Bulk density (g/cm^3)	1.50	1.51
Hydraulic cond.(cm/h)	0.67	0.16

* 1:2.5 soil : water

TABLE (2). Chemical composition of the saline well water used in irrigation.

pH	EC dS/m^{-1}	Soluble cations and anions (meq/L)								SAR
		Ca^{++}	Mg^{++}	K^+	Na^+	CO_3=	HCO_3-	Cl-	SO_4=	
7.7	8.2	25	28.80	0.96	38.8	-	2.10	56.32	35.14	7.49

SAR = Sodium Absorption Ratio

TABLE (3). Chemical analysis of sewage sludge used in this study.

pH*	EC* ds/m^{-1}	O.M %	N %	P	K	Fe	Mn	Zn
				**(mgkg^{-1})				
7.50	6.55	43.91	21.06	140.000	171.6	1612	105.40	129.20

*1:2.5 soil : water ** Total form

RESULTS AND DISCUSSION

(A)Soil Chemical Properties

Table (4) shows that pH values in the soil surface and sub surface decreased with increasing sewage sludge application rate. The decrease in soil pH values by sludge application may have been caused by intense nitrification of NH_4 –N and formation of organic acids and Hydrogen. Such decrement was also attributed to the mineralization of organic matter in sewage sludge (Wen *et al.*,1997).

TABLE (4). Effect of sludge treatment, on pH, EC, O.M and macronutrients (N,P,K) of soil after harvesting.

Soil Depth (cm)	*Method of rate Sewage sludge (ton/ fed)*				
	S_0	S_1	S_2	SU_1	SU_2
			*PH**		
0-10	8.46± 0.08	7.87± 0.21	7.88 ± 0.27	7.39± 0.58	7.71± 0.33
10-20	7.93 ± .24	7.38± 0.32	7.29 ± 0.22	7.29± 0.36	7.47± 0.19
			EC (dsm^{-1})*		
0-10	2.08± 1.02	3.00 ± 1.07	3.31 ± 0.64	2.61± 0.49	2.07± 0.00
10-20	1.21± 0.13	1.68± 0.38	2.12 ± 0.40	2.00± 0.00	2.64± 0.64
			O.M %		
0-10	1.04± 0.10	1.24± 0.13	1.24 ± 0.10	1.07± 0.10	1.00± 0.00
10-20	0.60±0.25	1.00 ± .03	1.10 ± 0.21	1.27 ± .20	1.35± 0.64
			Total N(mgkg^{1-})		
0-10	280 ± 154	520 ± 59	560 ± 218	400 ±29	400 ± 000
10-20	240 ± 67	390 ± 72	400 ± 72	460 ± 48	580 ± 67
			Available P (mgkg^{1-})		
0-10	3.20±0.92	9.00 ±1.42	12.30±1.64	5.80± 0.22	6.00 ± 00
10-20	1.80± .29	6.50± 1.88	6.50 ± 2.16	5.20± 0.72	6.40± 0.54
			Extractable K (mgkg^{1-})		
0-10	93.6 ± 37	156 ± 54	187.2 ± 54	70.2 ± 15	66.3 ± 13
10-20	54.6 ± 21	62.4 ± 41	85.8 ± 33	132.6±14.	152.1 ± 30

* 1:2.5 soil : water S= surface soil layer (0-10)

SU= subsurface soil layer (10-20)

The results given in table (4) show that the electrical conductivity of soil in 1:2.5 soil water extract progressively increased with increasing sewage sludge rates. With respect the surface application, such increase in soil salinity is certainly attributed to the salts contained in the sludge (Table3). EC at 10-20 soil depth, increased from 1.21 ds/m^{-1} at zero rate to 2.64 ds/m^{-1} at 20 ton /fed sludge rate. This could be mainly due to the mixed of sludge at different soil depths and not to the leaching process. These results come in line with those of Abou – seeda *et al.* (1984), Shiralipour *et al.* (1992) and Mohammad and Battikhi (1997).

Soil organic matter content was substantially increased from 1.04 % in the control treatment to 1.24% in the treatments with the higher sewage sludge rate with surface application (Table 4). Soil organic matter, as expected, showed a considerable build up as a result of addition of sewage sludge. Organic matter at 10-20 cm depth for 20 ton /fed sludge treatment was consistently higher than that for the control (Table 4). These results were similar to those reported by Park *et al.* (1991) and Mohammed Battikhi (1997).

Data in table (4) represent the contents of available P, exchangeable k and total N in the soil treated with different rates of sewage sludge with two methods of soil application. The obtained results showed an increase in the available P, exchangeable k and total N in all treatments , where such nutrients increased with increasing application rate of each application method. The obtained results are in harmony with that obtained by Ekeberg (1991).

Phosphorus is an immobile element in the soil because of a variety of fixation and precipitation processes. From the data of table (4), it is obvious that this movement was observed in the treatments of sewage sludge (S_2), it seems that organic matter of sewage sludge may affect either on P transpiration in soil or due to its high content of available phosphorus . Tsadilas and Samaras (1999) who found that the storage relationship between available P and organic matter content.

Exchangeable K was affected by sewage sludge application. It ranged from about 66.3 to 187.2 mg kg^{-1} soil in the surface layer and 54.6 to 152.1 mg kg^{-1} soil in the sub-surface layer . Similar observations were reported by several workers such as Smith (1996). Sewage sludge contains small quantities of K that do not increase K concentration, especially in soils well supplied with K .

Total N ranged from 240 to 560 mg kg^{-1} that was strongly influenced by the treatment applied in the whole both soil depths.

B- Soil Physical Properties

1- Water stable aggregates

The percentages of water stable aggregates in the soil is a good indicator of the state of soil structure and movement of water and air. The total amount of aggregates and the aggregate diameters in soil differ with both the quality and quantity of irrigation water (Kandil, 1990).

Data in table (5) show great variations in the percentages of soil aggregates as affected by method and rates of sewage sludge.

As regarding the aggregate size, the most responsive to the applied treatment was the size diameter of 0.5 – 0.25 mm. The surface application was the most effective one in enhancing the formation of size as compared with sub surface application. In the same sequence the total stable aggregates (> 0.25mm) were increased in the treated plots. The increment varied according to the method and rate of sewage sludge application. For instance, it can be noticed that total aggregates were highly increased at the surface soil layer by incorporating of sludge at 0-10cm depth, the total aggregates was 38.09 mm at S_2 compared to 18.47 mm at the control. While the total aggregates increased at the subsurface soil layer by incorporating of sludge at 10-20 cm depth, the total aggregates was 32.77 mm at SU_2 compared to 17.02 mm at the control. The positive effect of sewage sludge could be due to that such materials service as cementing agents. As the microbial decay of organic matter of these materials produces polymers (such as polysaccharides and polynuorinides) capable for binding soil aggregates (Hillel,1980).

Aggregation Index (AI) and structure coefficient (SC) values general increased with increasing the rate of application, this trend due to the behavior of the organic matter associated with seweg sludge, which may be an indication of the role of organic matter in aggregates formation. (Edwards and Bremner, 1967 and Amer *et al.*, 1986).

2- Bulk Density

The application of natural conditioner caused a remarkable decrease in soil bulk density as compared to the control. Evidently, the higher rate of application the more reduction in soil bulk density occurs (Table 5) .The rate of reduction varied according to the rate of the application sewage sludge. This suggests that the decrease in Pδ with increasing sludge application was due to increases in total porosity as a result of structural changes and not because of the lower Pp. of sludge compared to mineral soil (Lindsay and Logan, 1998). While the respective decrement pertaining incorporation amounted to 8.66% and 11.33% for the levels of SU_1 and SU_2, respectively.

Comparatively the studied sludge treatments could be arranged according to their efficiency on bulk density in the following order S_2> SU_2> S_1>SU_1>control.

3- Hydraulic Conductivity

Hydraulic conductivity is an important factor in the planning of water requirements for soil reclamation and artificial irrigation, since it is a measure of the rate of water conduction in the soil. The effect of sewage sludge treatments on hydraulic conductivity of studied soil is given in table (5), K values of sewage sludge treatments are very low. The Hydraulic conductivity decreased by 39% and 49% due to S_1 and S_2 at (0-10cm) soil depth . Also the decrement percent associated with incorporated sewage sludge with 10-20cm soil depth were 50% and 60% for the Su_1 and Su_2 level, respectively . Similar results were also obtained by Gupta *et al.* (1977).

TABLE (5). Some physical properties of soil as affected by sewage sludge under saline irrigation water.

Treatments	Depth (cm)	Aggregate size distribution % (mm)				Total >0.25	AI *	SC **	Bulk. density g/cm^3	K (cm/h)
		>2.0	2.0-1.0	1.0-0.5	0.5-0.25					
S_0	0-10	0.58	0.36	4.44	13.09	18.47	0.055	0.226	1.50	6.3
	10-20	0.56	0.35	5.01	11.10	17.02	0.062	0.205	1.45	8.82
S_1	0-10	0.46	0.38	13.12	21.72	35.68	0.078	0.546	1.35	3.84
	10-20	0.48	0.56	11.86	18.38	31.28	0.067	0.455	1.36	6.3
S_2	0-10	0.30	0.33	11.30	26.16	38.09	0.095	0.615	1.28	3.18
	10-20	0.34	0.50	9.64	19.26	29.74	0.072	0.238	1.30	7.98
SU_1	0-10	0.46	0.32	12.41	13.30	26.49	0.077	0.360	1.37	6.3
	10-20	0.60	0.36	13.10	13.98	28.04	0.083	0.389	1.28	3.12
SU_2	0-10	0.39	0.45	11.17	19.00	31.07	0.065	0.449	1.33	6.12
	10-20	0.52	0.44	12.64	19.17	32. 77	0.109	0.487	1.26	2.52

* Aggregation Index ** Structure Coefficient

C) Wheat yield and Nutrient content

The surface application of sewage sludge led to a significant increases in wheat grains and / or straw yield (Table 6). The rate of increment over the control reached 59.88 %, 103.12 % for straw and 35.5 %, 88.78 for grains, respectively.

The positive effect of sewage sludge on increasing wheat yield is a true reflection of physical and chemical properties of soil affecting the plant growth such as improving soil aggregation and increasing water stable aggregates, increase of the soil water retention due to its effect on pore size distribution, i - e water holding pores decreasing soil pH values which led to increase nutrient availability and stimulates biodegradation through increasing the population and activities of soil microorganisms(Gouda, 1984; Mostafa, 1986; Dahdoh and El-Hassanin, 1994 and Mervat and Dahoh,1997). While on adding sludge as incorporating through 10-20 soil depth (SU treatment) as compared with S treatment reached 23.25% ,50% for straw and 22.4 % and 25.30% for grains.

The reduction of wheat yield as compared to adding sludge as a layer was mainly attributed to the absorption of elements depending upon the mobility of elements through the root zone in the calcareous soil. The $CaCO_3$ of such soil can react with the released nutrients and reduce their availability and the effects of salinity of sludge on growth, physiological processes and metabolic activities of growing plants. Also, it may be due to the harmful effect of salinity on soil moisture stress and nutrient balance disorder in the root medium (Fayed, 1988).

TABLE (6). Effect of sludge rate and application method on wheat yield, (N, P, K) concentration and heavy metal under saline irrigation water.

Parameter	*Sludge Rate T/fad*					
	S 0	S1	S2	SU1	SU2	LSD at 5 %
			Yield ton/fad			
straw	1.59	2.75	3.61	2.12	2.41	0.475
Grain	1.07	1.45	2.02	1.33	1.54	0.508
			N %			
Straw	1.37	1.54	1.67	1.28	1.52	0.909
Grain	1.62	2.00	2.71	1.71	1.92	0.296
			P ($g.kg^{-1}$)			
Straw	0.24	0.28	0.37	0.28	0.35	0.080
Grain	0.30	0.32	0.34	0.36	0.30	0.057
			K ($g.kg^{-1}$)			
Straw	0.36	0.40	0.42	0.45	0.48	0.068
Grain	0.40	0.46	0.48	0.48	0.55	0.058
			Fe($mg.kg^{-1}$)			
Straw	70.25	81.00	88.00	84.00	97.00	3.840
Grain	86.00	90.00	104.00	103. 0	108.00	3.680
			Mn($mg.kg^{-1}$)			
Straw	22.00	25.00	31.00	26.40	30.00	2.95
Grain	24.00	28.00	45.00	28.00	33.60	2.46
			Zn($mg.kg^{-1}$)			
Straw	28.00	43.00	60.00	33.00	51.00	2.80
Grain	40.35	60.00	61.33	40.00	77.01	24.227

Regarding the interaction between the studied treatments (rates and methods), these have no significant effect on grain and straw yield, while the interaction effect on values of the concentration of the studied elements parameters showed different trends that varied widely due to the rate and /or the method of applying sludge.

Data in table (6) exhibited that increasing sludge application elevated concentrations of N, P, K, Fe, Mn and Zn in wheat grains and/or straw yield. The highest values of such elements are associated with the higher rates of sludge with any application method, however the variation in the rate of increase may be due to the plant growth, where it increased significantly with increasing the rate of sludge application with exception of nitrogen concentrate at SU1 straw and P, (S1) grains.

The relative beneficial effect of such material on lowering soil pH values and consequently increasing the availability of N, P, K, Fe, Mn and Zn, beside the higher initial content of such nutrient in sludge (Table 3, Ibrahim, 1998). The application methods of sludge is also effective in a way that incorporating such material by 0-10 cm soil surface show superior effect on increasing the concentrations of N, P, K, Fe, Mn and Zn compared to the other methods of application.

The positive effect of such materiel on nutrient concentration may be due to its effect on lowering soil pH (Table 4)

From the aforementioned discussion, it can be concluded that incorporating 20 ton /fed sewage sludge with soil surface of 0-10cm is the best treatment under saline irrigation water.

TABLE (7). Effect of the method of application on wheat yield and N,P,K, Fe, Mn , Zn concentration regardless of its rates.

Method of application	Yield ton/fed		Grain						Straw					
			N	P	K	Fe	Mn	Zn	N	P	K	Fe	Mn	Zn
	G	S	%		g/kg		mg/kg		%		g/kg		mg/kg	
M1	1.51	2.65	2.11	0.32	0.44	93.33	32.33	54.61	1.52	0.29	0.39	79.75	26.00	43.66
M2	1.31	2.04	1.75	0.32	0.47	99.00	28.33	52.58	1.39	0.29	0.43	83.75	26.10	37.33
State of significance at 0.05	s.g	s.g	s.g	n.s	n.s	n.s	s.g	n.s	n.s	n.s	n.s	s.g	n.s	s.g

Data in table (7) show the main effect of application method of sludge on yield (G,S)and N, P, K ,Fe, Mn and Zn concentration regardless of its rates. It is clear that the grain yield and its nutrient content of N and Mn also the straw yield and its nutrient content of Zn and Fe were affected significantly at 5% level.

TABLE (8). Effect of the rates of application sludge on wheat yield and N,P,K, Fe, Mn, Zn concentration regardless of its method.

Rates of application	Yield		Grain						Straw					
	ton/fed		N	P	K	Fe	Mn	Zn	N	P	K	Fe	Mn	Zn
	G	S	%		g/kg		mg/kg		%		g/kg		mg/kg	
S0	1.07	1.59	1.62	0.30	0.40	86	24.0	40.75	1.37	0.24	0.36	70.25	22.0	28.0
S1	1.39	2.43	1.89	0.34	0.47	96.5	28.0	50.0	1.41	0.28	0.42	82.5	25.5	38.0
S2	1.78	3.01	2.13	0.32	0.51	106.0	39.0	69.35	1.59	0.36	0.45	92.5	30.5	55.5
L.S.D 0.05	0.36	0.34	0.21	0.05	0.04	2.72	2.08	17.13	0.20	0.06	0.05	2.36	1.74	2.69

Data in table (8) show the main effect of application rates of sludge on yield and N, P, K, Fe, Mn and Zn regardless of its method of application. It is clear that the grain yield and its nutrient content of N ,K and Fe also the straw yield and its nutrients content of K, Fe and Mn were affected significantly at 5% level .

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تقيم إضافة البودريت كمحسن طبيعي للتربة تحت ظروف الري بالمياه المالحة

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نظرا لندرة مياه الري الجيدة للزراعة ولحتمية التوسع الزراعي الأفقي وعمليات استصلاح الأراضي مما يتطلب استخدام مياه ذات نوعية أقل جودة . فقد أقيمت تجربة حقلية بمحطة بحوث رأس سدر لدراسة تأثير طرق ومعدلات إضافة البودريت تحت ظروف الري بمياه عالية الملوحة وتأثير ذلك على خواص الأراضي الجيرية وإنتاجيتها من محصول القمح بهدف إمكانية الاستفادة من البودريت كمحسن طبيعي واشتملت معاملات الدراسة على ما يلى :

- معدلات إضافة ١٠ ، ٢٠ طن / فدان .
- طرق الإضافة [خلط سطحي (صفر - ١٠ سم) وخلط تحت سطحي (١٠-٢٠سم)]

وقد أشارت النتائج إلى:

[١] أدى زيادة معدل إضافة البودريت إلى انخفاض قيم pH التربة في حين ازدادت قيم التوصيل الكهربى والمادة العضوية وتيسر عناصر منجنيز - نيتروجين - فوسفور - بوتاسيوم - زنك وقد اختلفت معدلات زيادة هذه القيم من عنصر إلي أخر إلا أن أعلى قيمة كانت مرتبطة بمعدل الإضافة المرتفع ٢٠ طن/فدان وباستخدام طريقة الخلط مع الطبقة السطحية للتربة.

[٢] تحسن البناء للأرض تحت الدراسة وذلك بزيادة التجمعات الثابتة وقد تفاوتت نسب الزيادة حسب المعدل وطرق إضافة البودريت بينما انخفضت الكثافة الظاهرية بزيادة معدل الإضافة

[٣] ازدادت إنتاجية المادة الجافة لمحصول القمح زيادة معنوية وبقيم مختلفة وذلك بزيادة معدل إضافة وطريقة إضافة البودريت وكانت أعلى إنتاجية بإضافة ٢٠ طن/فدان خلطا بالطبقة السطحية وقد انعكس ذلك على زيادة تركيز عناصر منجنيز - حديد - نيتروجين - فوسفور - بوتاسيوم - زنك وفى جميع الأحوال كلما زاد معدل إضافة البودريت.