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Impact of Sewage Sludge as Organic Manure on Some Soil Properties, Growth, Yield and Nutrient Contents of Cucumber Crop

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Abstract: The present study was conducted in two field experiments with two soil types (sandy and calcareous soils) under greenhouse conditions at the Agricultural and Veterinary Training and Research Station of KFU, Al-Hassa area. The objective of the present study was to investigate the effects of different rates of sludge on some soil properties, growth, yield and nutrients status of leaves and fruits of cucumber plant. The experimental soils have sandy and sandy loam textures. All experimental plots (6 m^2 area) cultivated with cucumber. Soil application of sewage sludge, at rates of 0 (control, with no sewage sludge), 25, 50, 75, 100 and 125 t ha^{-1} was used in the present study. Sewage sludge was mixed with top 30 cm surface layer of each plot, two month before planting of cucumber. The experiments were conducted in a randomized complete block design with 3 replications. The experimental plots received the same agricultural practices as recommended. The obtained results revealed that application of sewage sludge significantly altered the chemical properties of soil. Soil Electrical Conductivity (EC), soluble cations (calcium, magnesium, sodium and potassium), soluble anions (chloride and sulphate), available phosphorous and micronutrients (iron, manganese, copper and zinc) and heavy metals (cadmium, cobalt, lead and nickel) were increased in sandy and calcareous soils with increasing sewage sludge application rate. While, the soil reaction (pH) and HCO_3^- contents were decreased as a result of sludge application. Also, application of sewage sludge improved physical properties of sandy and calcareous soils. It decreased the soil bulk density and increased saturation water content, porosity and organic matter content. Application of sewage sludge improved leaves and fruit contents of macro- and microelements of cucumber plant grown in sandy and calcareous soils. Also, the number of fruits and yield of cucumber were increased with increasing the rates of sewage sludge application. The highest level of application of sludge has a highest effect on the yield of cucumber plants. Generally, application of sewage sludge by mixing it with top 30 cm soil layer was found to be more effective in improving soil physical, chemical and fertility conditions. Moreover, using of sewage sludge as organic manure is considered as a source of nutrients that required for plant which led to increase the growth and the yield of cucumber crop.

Key words: Sewage sludge, heavy metals, organic manure, soil properties, cucumber crop

INTRODUCTION

Sewage sludge is the insoluble residues from municipal wastewater treatment after either aerobic or anaerobic digestion processes. Increasing costs of commercial fertilizers and large amounts of sewage sludge produced worldwide have made cropland application of this residue an attractive disposal option. Chemical and biological compositions of sewage sludge depend on the wastewater composition (Melo *et al*., 2002). Usually, it is rich in Organic Matter (OM) and plant nutrients such as nitrogen (N), phosphorus (P) and calcium (Ca) (Hue, 1988) and can improve soil physical, chemical and biological properties, such as porosity, aggregate stability, bulk density, soil fertility, water movement and retention (Silveira *et al*., 2003).

The soils of arid and semiarid regions have low organic carbon content and then need organic amendments to improve their physicochemical and biological properties and thus their productivity and natural fertility (Pascual *et al*., 1997). The substantial N and P concentrations in sludge render are a useful fertilizer material and its organic constituents give it beneficial soil conditioning properties. The improved aeration and drainage following sludge amendments can have indirect effects on the soil-plant relationships of heavy metals through affecting growth, nodulation in leguminous plants and other properties (Roberts *et al*., 1988). The availability of heavy metals in the sewage sludge and soils treated with sewage sludge depends on many factors such as the properties and amount of heavy metals, the partitioning of heavy metals between solution and solid phase and soil characteristics (Jin *et al*., 1996). It is widely known that the bioavailability of heavy metals in soil is strongly influenced by the amount and the quality of organic matter that can react with the heavy metals, forming complexes and chelates of varying stability (Leita *et al*., 1999). There is an increasing interest in the agricultural application of sludge obtained from wastewater treatment plants, due to the possibility of recycling valuable components; organic matter, N, P and other plant nutrients (Suss, 1979).

Therefore, the main problems of an excessive application of sewage sludge are plant toxicity due to accumulation of heavy metals in soils (McGrath *et al*., 2000) but also the increase in its salt content (Hao and Chang, 2003). The fertility benefit must be balanced against the potential hazards of metal contamination through application of sludge to agricultural productive.

Many studies have been published on the beneficial effects of sewage sludge amendment on crop yield and some soil physical and chemical properties. The addition of sludge to soil is known to improve the soil physical properties as evidenced by (a) increasing water content, (b) increasing water retention, (c) enhanced aggregation, (d) increased soil aeration, (e) greater permeability, (f) increased water infiltration and (g) decreased surface crusting. Antoline *et al.* (2005) reported that application of sewage sludge decreased soil pH and increased total soluble salts, organic carbon and cation exchange capacity of the soil. Also, they found that application of sewage sludge increased soil DTPA-extractable heavy metals (Cd, Cu, Mn, Pd and Zn) and increased $N\text{-}NH_4^+$ content of the soil. Mendoza *et al.* (2006) reported that organic matter and extractable (Cu, Zn, Ni, Pb, Mn and Fe) increased with addition of sludge to the soil while soil pH decreased.

Elsokkary and El-Keiy (1988) and Elsokkary *et al.* (1989) found that sewage sludge application increased the dry weight yield and grain yield of alfalfa, wheat, fababean and soybean. Zaid (1989) reported that yield of corn increased in sandy soil and calcareous soil as sewage sludge rate increased. Many studies appeared that adding sludge to the soil promotes plant growth significantly more than when commercial fertilizer is added. Christodoulakis and Margaris (1996) showed that plant height increased in maize individuals by 77% in the sludge amended treatment compared to 25% in the case of the commercial fertilizer amendment.

Elsokkary and El-Keiy (1988) and Elsokkary *et al.* (1989) found that sewage sludge application increased the concentrations of (P, K, Fe, Mn, Cu, Zn, Co, Ni, Pb and Cd) in leaves and grain of alfalfa, wheat, fababean and soybean. However, no visual symptoms of metal toxicity showed on the different plant species. Hussein (1991) reported that sludge application significantly increased the Ca, Mg, K, N, Fe, Mn, Cu and Zn in corn, sugar beet and cotton plants. Also he found that, the yield of the three crops increased by application of sewage sludge. Antoline *et al.* (2005) found that N content in grain of barley increased as a result of addition of sludge to the soil. Also, they noticed that grain heavy metals (Cd, Cr, Mn, Ni, Pd, Cu and Zn) of barley increased with addition of sludge to the soil. Mendoza *et al.* (2006) reported that the concentration of (Cu, Mn, Pb and Fe) increased in leaves of sorghum grown in soil amended with sludge.

The aim of the present study is to investigate the effects of different rates of sludge on some soil physical and chemical properties, growth, yield and elemental contents of leaves and fruits of cucumber plant.

MATERIALS AND METHODS

The present study was conducted in two field experiments at two different soil types (sandy soil and calcareous soil) under greenhouse conditions at the Agricultural and Veterinary Training and Research Station at King Faisal University (KFU), Al Hassa region, Saudi Arabia. Some physical and chemical characteristics were determined at the beginning of the growing season before application of sewage sludge. The analysis of soil samples collected from the plough layer (30 cm depth) was done according to the methods outlined in Carter (1993) and the data are shown in Table 1. Sewage sludge was applied at rates of 0 (control, with no sewage sludge), 25, 50, 75, 100 and 125 t ha^{-1}. Sewage sludge was mixed with the top 30 cm surface layer of each plot, two months before planting of cucumber. Sewage sludge used in the present study was taken from the Waste Water Treatment Organization, Al Hassa region. Some characteristics of sewage sludge used in the present study are shown in Table 2 after determination with standard methods according to Carter (1993).

Cucumber (*Cucumis sativus*) variety Yasmeen, was planted at 30 cm apart between hills in the prepared plots on September 6, 2007, each plot has a size of 6 m^2 (three rows 65 cm apart and 3 m long). The experiment was conducted in randomized complete block design with 3 replications. The frequency of irrigation is largely dependent on soil type and weather conditions. In general, the soil plots were irrigated at least every two days. All plots, received the fertilizers requirements as recommended for cucumber. All plots were received 150 kg of P_2O_5 ha^{-1} before planting in the form of calcium super-phosphate (15.5% P_2O_5). Nitrogen fertilization as ammonium nitrate (33.5% N) at rates of 450 kg of N ha^{-1}

Table 1: Some physical and chemical properties of the experimental soil

Property	Sandy soil	Calcareous soil
Particle size distribution (%)		
Sand	92.32	59.12
Silt	2.00	24.00
Clay	5.68	16.68
Textural class	Sand	Sandy loam
Saturation water content (%)	24.50	37.80
Organic matter (%)	0.12	0.16
$CaCO_3$ (%)	26.00	27.90
Total N (%)	0.04	0.13
EC_e (soil paste) (dS m^{-1})	1.12	1.26
pH (soil paste)	7.11	7.99
Soluble cations (meq L^{-1})		
Na^+	1.51	1.71
K^+	0.72	0.71
Ca^{++}	5.51	6.47
Mg^{++}	3.27	3.67
Soluble anions (meq L^{-1})		
CO_3^{-2}+HCO_3^-	1.15	1.30
Cl^-	5.72	6.21
SO_4^{-2}	4.01	4.79
Available P (mg kg^{-1})	4.55	5.65
Available K (mg kg^{-1})	18.31	41.64
Extractable micronutrients (mg kg^{-1})		
Fe	0.01	0.04
Mn	1.05	2.30
Cu	0.01	0.10
Zn	0.12	0.33
Extractable heavy metals (mg kg^{-1})		
Cd	0.013	0.011
Co	0.011	0.046
Ni	0.042	0.186
Pb	0.157	0.402

Table 2: Main chemical characteristics of sewage sludge

Variables	Level
EC (1:2, water extract) (dS m^{-1})	5.59
pH (1:2, water suspension)	6.56
Soluble cations (meq L^{-1})	
Na^+	7.20
K^+	5.70
Ca^{++}	27.40
Mg^{++}	16.60
Soluble anions (meq L^{-1})	
CO_3^{-2}+HCO_3^-	15.60
Cl^-	30.00
SO_4^{-2}	9.70
Organic matter (%)	28.60
Total N (%)	2.31
C/N ratio	7.18
Available P (mg kg^{-1})	250.00
Available K (mg kg^{-1})	129.70
Available micronutrients (mg kg^{-1})	
Fe	108.50
Mn	47.30
Cu	27.90
Zn	298.80
Available heavy metals (mg kg^{-1})	
Cd	0.21
Co	0.23
Ni	3.69
Pb	27.50

was divided into three equal doses; the first dose was applied two weeks after planting, the second dose at the begging of fruit and the third dose two weeks later. Potassium fertilization was applied in the form of potassium sulphate (48% K_2O) at 150 kg of K_2O ha^{-1} at two equal doses, the first dose was applied before planting and the second dose was one month later.

For tissue analysis, leaf samples of about 20 leaves from five plants (70 days old) of each plot were taken to represent a composite leaf sample (leaf sample was collected from location below the last open flower clusters, prior to the fruiting stage). Also, time from planting to first harvest is 70 days. The frequency of harvest is usually every other day depending on weather and plant vigor (cooler temperatures, growth will be slightly slower). At harvest time, number of fruits per plant was recorded and samples of 15 fruits were randomly collected from each plot. Leaf and fruit samples were washed with tap water, distilled water, air-dried (fruit samples cutting to slides), oven dried at 65C° for 72 h and then ground in a stainless steel mill and the powder stored for elemental analysis. The plant powder was digested with concentrated sulphuric acid + 30% hydrogen peroxide according to the method of Wolf (1982). Total nitrogen was determined by using the micro-Kjeldahl method (Jackson, 1973). In the digest, total phosphorus was determined colorimetrically according to the method of Murphy and Riley (1962). Total potassium was determined by flame photometry according to Jackson (1973). Total calcium and magnesium were determined by atomic absorption spectrophotometer according to Carter (1993). Fe, Mn, Cu, Zn, Cd, Co and Ni were determined by inductively coupled plasma optical emission spectrometer (Carter, 1993).

At the end of season, representative soil samples were taken by soil auger from each plot to a depth of 30 cm. All the collected soil samples were air dried, grounded and sieved through a 2 mm sieve and kept for physical and chemical analysis. Soil Bulk Density (BD) was determined according to the standard methods outlined by Klute (1986). Total porosity was calculated as percentage from the values of real and bulk densities (Hillel, 1980). The pH and total soluble salts were measured in the soil paste extract (Rhoades, 1982). Sodium and potassium were determined by flame photometry according to Jackson (1973). Calcium and magnesium were determined by atomic absorption spectrophotometer according to Carter (1993). Soluble carbonates and bicarbonates were determined volumetrically in the soil paste extract by titration against 0.01 N hydrochloric acid using phenolphthaline and methyl orange as indicators according to Jackson (1973). Soluble chlorides were determined by titration with 0.01 N silver nitrate solution and potassium chromate as indicator according to Richards (1954). Available phosphorus was extracted using Na bicarbonate extraction (Olsen *et al*., 1954).

Phosphorus was determined using chlorostannous phosphomolybdic acid method (Jackson, 1973). Organic matter content was determined according to Walkley-Black rapid titration method (Jackson, 1973). The Fe, Mn, Cu, Zn, Cd, Co, Ni and Pb were extracted using DTPA-extraction method (Lindsay and Norvell, 1978), then determined by inductively coupled plasma optical emission spectrometer (Carter, 1993).

The collected data were subjected to statistical analysis of variance according to SAS Software (SAS Institute Inc., 1996).

RESULTS AND DISCUSSION

Soil chemical properties: Soil Electrical Conductivity (EC), soluble cations (calcium, magnesium, sodium and potassium), soluble anions (chloride and sulphate), available phosphorous, available micronutrients (iron, manganese, copper and zinc) and heavy metals (cadmium, cobalt, lead and nickel) were significantly increased in both sandy and calcareous soils with increasing sewage sludge application rate. On the other hand, sludge applications decreased the soil reaction (pH) and HCO_3^- content (Table 3, 4). Also, the data showed that there were a significant correlation between application of sludge and some soil chemical properties (Table 5).

Generally, these changes in the chemical properties of sandy soil and calcareous soil after sludge application are related to the chemical composition of the added sludge. Barzegar *et al.* (2002) and Veeresh *et al.* (2003) noticed that sludge application improves chemical properties of soils due to the addition of organic matter. As regard to soil pH, the reduction in soil pH was more pronounced at high rates of sludge application. The decrease in soil pH is due to organic acids produced during sludge decomposition. Another explanation, the reduction in soil pH probably due to nitrification of N-NH_4^+ from the sludge (Stamatiadis *et al.*, 1999). Similar results were obtained by Abdel-Nasser and Harhash (2000), Abdel-Nasser and Hussein (2001) and recently by Mendoza *et al.* (2006). Also, the decrease in the pH values observed in this experiment agrees with the findings of Hooda and Alloway (1993), who describe an initial increase of 1.5 pH units after amending soil with 50 t ha^{-1} sludge and a further pH decrease to lower values than the control soil. This effect would be attributed to the presence of significant amounts of mineralizable N and degradable organic matter in sludge.

On the contrary increased soil electrical conductivity as a result of sludge application may be attributed to the high salt content of sludge as shown in Table 2. The present results are in agreement with those reported by

Table 3: Effect of sewage sludge applications on chemicals properties of sandy soil

Applied sludge (t ha^{-1})	pH	EC (dS m^{-1})	Cations				Anions			Available	Available micronutrients				Heavy metals			
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^-	SO_4^{-2}	P	Fe	Mn	Cu	Zn	Cd	Co	Ni	Pb
			(meq L^{-1})							(mg kg^{-1})								
0	7.84	1.55	1.31	3.03	7.17	3.75	4.96	1.84	7.89	5.12	1.01	1.25	0.23	4.29	0.011	0.027	0.105	0.165
25	7.61	1.65	1.35	3.53	8.02	3.93	5.51	1.69	8.24	8.23	1.63	1.33	0.28	11.39	0.040	0.028	0.122	0.245
50	7.58	1.75	1.64	3.89	8.35	3.93	5.51	1.56	8.98	10.34	4.81	1.58	0.93	12.72	0.040	0.041	0.162	0.248
75	7.49	1.86	1.97	3.99	8.76	4.16	6.20	1.40	9.14	13.21	6.77	1.68	1.44	14.49	0.043	0.041	0.180	0.458
100	7.46	2.14	2.26	4.05	10.16	5.22	7.99	1.23	9.71	16.29	7.11	2.42	1.45	20.75	0.053	0.047	0.278	0.545
125	7.39	2.61	2.87	5.05	12.13	6.49	10.33	1.08	12.02	18.11	16.5	4.08	3.81	31.59	0.062	0.059	0.362	1.032
LSD (0.05)	0.03**	0.78**	0.07**	0.10**	0.14**	0.28**	0.12**	0.08**	0.27**	0.77**	0.78**	0.05**	0.20**	1.61**	0.02**	0.01**	0.02**	0.02**

Table 4: Effect of sewage sludge applications on chemicals properties of calcareous soil

Applied sludge (t ha^{-1})	pH	EC (dS m^{-1})	Cations				Anions			Available	Available micronutrients				Heavy metals			
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^-	SO_4^{-2}	P	Fe	Mn	Cu	Zn	Cd	Co	Ni	Pb
			(meq L^{-1})							(mg kg^{-1})								
0	7.75	1.72	1.58	2.22	8.43	4.78	5.03	1.91	8.45	7.00	0.74	1.91	0.33	16.38	0.018	0.027	0.173	0.417
25	7.74	1.89	1.71	2.33	9.48	5.21	5.99	1.77	9.65	10.14	4.25	3.18	0.92	16.92	0.027	0.033	0.228	0.495
50	7.72	2.08	2.11	2.38	10.25	5.83	6.95	1.62	10.69	12.27	5.39	3.21	1.07	19.41	0.049	0.035	0.236	0.535
75	7.62	2.15	2.30	2.73	10.30	5.89	7.18	1.59	10.89	15.35	8.04	3.12	1.61	26.87	0.052	0.042	0.342	0.640
100	7.44	2.21	2.52	2.80	10.61	5.92	7.25	1.45	11.55	17.41	9.54	4.02	2.39	29.86	0.061	0.048	0.370	0.708
125	7.27	2.65	3.80	3.46	11.68	7.27	8.71	1.21	13.44	20.19	28.05	6.01	6.05	52.3	0.062	0.058	0.598	1.903
LSD (0.05)	0.07**	0.15**	0.19**	0.13**	0.21**	0.34**	0.75**	0.21**	0.54**	0.46**	3.17**	0.95**	0.37**	3.35**	0.01**	0.01**	0.02**	0.03**

Table 5: Correlation coefficients between sludge application and some soil chemical properties

Variables	pH	EC	P	Fe	Mn	Cu	Zn	Cd	Co	Ni	Pb
Sandy soil	-0.94	0.94	0.99	0.92	0.87	0.89	0.95	0.92	0.96	0.95	0.91
Calcareous soil	-0.93	0.96	0.99	0.86	0.89	0.87	0.89	0.95	0.98	0.93	0.78

Abdel-Nasser and Harhash (2000), Abdel-Nasser and Hussein (2001) and Mendoza *et al.* (2006). Also, increasing the available nutrients level may be due to the acidity produced by sludge decomposition and its effects on solubility of some soil minerals or due to releasing the nutrients through sludge decay by micro-organism's activity. Also, increasing the soil available nutrients may be attributed to the high content of such element in sludge used (Table 2). May *et al.* (1973) showed that incorporation of compost made from municipal refuses and sewage sludge, over a 2 year period, significantly increased K, Ca, Mg and Zn levels in the soil and decreased soil pH. Antoline *et al.* (2005) reported that application of sewage sludge decreased soil pH and increased total soluble salts of the soil. Also, they observed that application of sewage sludge increased soil DTPA-extractable heavy metals (Cd, Cu, Mn, Pd and Zn) and increased $N\text{-}NH_4^+$ content of the soil.

The effect of sludge on the status of P and micronutrient availability in the used soil should be evaluated. According to the critical levels of P determined by Olsen's *et al.* (1954) method (Bingham, 1962), it seems that the concentration of P in sandy and calcareous soils was low at zero sludge (control), but at 25-50 t ha^{-1} sludge application, the concentration of P in sandy soil ranged between 8.23-10.34 mg kg^{-1} and 10.14-12.27 mg kg^{-1} in calcareous soil (moderate). At 75-125 t ha^{-1} sludge application, the concentration of P in sandy soil ranged between 13.21-18.11 mg kg^{-1} and 15.35-20.19 mg kg^{-1} in calcareous soil (high).

According to Follet and Lindsay (1970), the concentrations of Zn, Cu and Mn in sandy soil and calcareous soil treated with sludge were adequate. Also, the concentration of Fe in sandy soil treated with sludge was deficient at 0 and 25 t ha^{-1}, but at 50-125 t ha^{-1} sludge it ranged between 4.81-16.5 mg kg^{-1} soil (adequate). The concentration of Fe in calcareous soil treated with sludge was deficient at 0 (control) sludge application, but at 25 t ha^{-1} it reached to 4.25 mg kg^{-1} soil (marginal) and at 50-125 t ha^{-1}, the concentration of Fe ranged between 5.39-28.05 mg kg^{-1} soil (adequate). Typical amount of risk element (Cd, Co, Ni and Pb) in non polluted soil are (0.01-3, 1-40, 10-1000 and 2-200 mg kg^{-1} for Cd, Co, Ni and Pb, respectively (Vecera *et al.*, 1999). According to Vecera *et al.* (1999) the concentration of Cd, Co, Ni and Pb in sandy soil and calcareous soil treated with sludge were within the normal range.

Regression between sludge application and some chemical properties of sandy and calcareous soils were fitted. The correlation coefficients were ranged between 0.8801 and 0.9949.

Table 6: The impact of sewage sludge on physical properties of sandy soil

Applied sludge (t ha^{-1})	Saturation water content (%)	Bulk density (g cm^{-3})	Porosity (%)	Organic matter (%)
0	24.5	1.73	34.72	0.28
25	25.8	1.70	35.85	0.31
50	27.5	1.65	37.74	0.46
75	28.2	1.59	40.00	0.56
100	29.1	1.55	41.51	1.07
125	30.5	1.52	42.64	2.40
LSD (0.05)	0.28**	NS	1.07**	0.61**

Table 7: The impact of sewage sludge on physical properties of calcareous soil

Applied sludge (t ha^{-1})	Saturation water content (%)	Bulk density (g cm^{-3})	Porosity (%)	Organic matter (%)
0	37.8	1.55	41.51	0.33
25	38.9	1.52	42.64	0.41
50	42.3	1.49	43.77	0.48
75	44.9	1.45	45.28	1.30
100	46.1	1.43	46.04	1.47
125	48.0	1.40	47.17	2.97
LSD (0.05)	0.98**	NS	0.52**	0.31**

Soil physical properties: Increasing the sewage sludge application rate significantly increased saturation percentage, porosity and organic matter content in sandy and calcareous soils. Bulk density insignificantly decreased in both soils with increasing sludge addition (Table 6, 7). These results indicated that physical properties of sandy and calcareous soils improved by the addition of sludge. This might be due to the high content of the organic matter (28.6%) in sewage sludge. Also, the data showed that there were a positive significant correlation between application of sludge to the soil and some soil physical properties (saturation percentage, porosity and organic matter). The correlation coefficients were 0.99, 1.0 and 0.85, respectively for sandy soil. The corresponding values for calcareous soil were 0.99, 1.0 and 0.91, respectively. On the contrary, the soil bulk density has a negative correlation with application of sludge to the soil. The correlation coefficients were -0.9945 and -0.9865 for sandy and calcareous soils, respectively.

The reduction in bulk density as a result of sludge application may be due to the homogeneous distribution of the manure constituents between soil particles and also the decomposition of sludge by micro-organisms, produces many essential cementing materials that can link the soil particles and forming soil aggregates (Kohnke, 1982). Similar results were obtained by Abdel- Nasser and Harhash (2000) and Abdel- Nasser and Hussein (2001). Antoline *et al.* (2005) and Mendoza *et al.* (2006) reported that application of sewage sludge increased organic matter of the soil. Such results were found in many literatures. Sewage sludge significantly increased

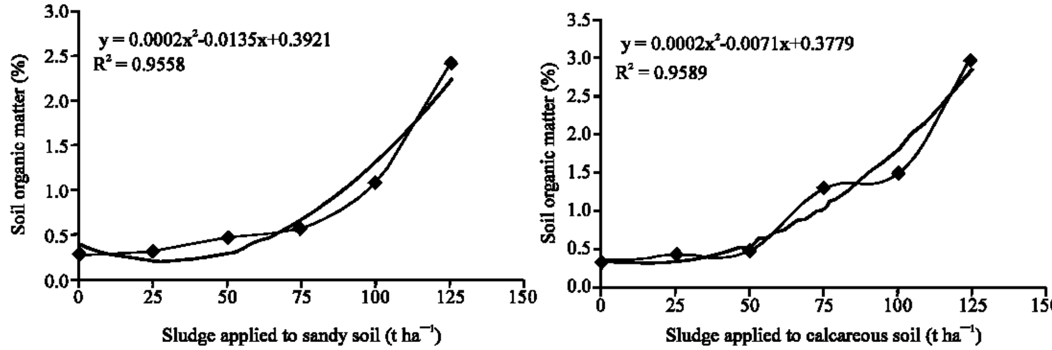

Fig. 1: Regression between sludge application to soil (t ha^{-1}) and soil organic matter content (%)

Table 8: The impact of different rates of sludge on elemental contents of cucumber leaves grown in sandy soil

Applied sludge (t ha^{-1})	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Cd	Co	Ni
	(%)					(mg kg^{-1})						
0	2.550	0.729	4.044	2.226	0.470	94.9	20.1	6.2	22.1	0.363	0.693	0.626
25	3.000	0.768	4.107	2.338	0.477	104.2	20.5	7.2	27.8	0.412	0.765	0.743
50	3.400	0.792	4.197	2.379	0.492	109.6	21.8	8.8	31.6	0.431	0.77	0.843
75	3.700	0.809	4.398	2.403	0.494	112.2	24.1	9.6	34.7	0.458	0.82	0.881
100	4.000	0.840	4.437	2.571	0.499	117.0	34.2	9.9	46.6	0.459	0.859	0.891
125	4.500	0.872	4.583	2.597	0.500	130.8	36.8	10.7	56.7	0.487	0.964	1.158
LSD (0.05)	0.33**	0.06**	0.34*	NS	NS	13.18**	4.23**	0.16**	5.20**	0.02**	NS	0.14**

Table 9: The impact of different rates of sludge on elemental contents of cucumber leaves grown in calcareous soil

Applied sludge (t ha^{-1})	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Cd	Co	Ni
	(%)					(mg kg^{-1})						
0	2.810	0.634	3.983	2.058	0.410	83.4	19.8	6.8	21.7	0.452	0.534	0.571
25	3.150	0.688	4.148	2.19	0.501	90.4	22.7	6.9	26.9	0.461	0.591	0.713
50	3.600	0.742	4.152	2.348	0.502	108.7	23.4	8.7	31.8	0.476	0.661	0.841
75	4.120	0.784	4.185	2.374	0.503	112.2	24.4	9.7	47.7	0.481	0.714	0.951
100	4.450	0.794	4.194	2.394	0.508	125.4	26.0	10.2	51.6	0.488	0.746	1.106
125	4.850	0.805	4.196	2.647	0.521	128.4	37.9	10.6	68.3	0.521	0.803	1.427
LSD (0.05)	0.34**	0.05**	NS	0.20**	0.06*	9.57**	1.49**	0.57**	1.32**	0.02**	NS	0.09**

saturation percentage and porosity of the soil, while, bulk density significantly decreased with increasing sludge addition to the soil (Hussein, 1991). Using organic manures resulted in improving soil physical properties such as soil porosity (Abdel-Nasser and Harhash, 2000; Abdel-Nasser and Hussein, 2001). Regression between sludge applications and soil organic matter content (%) was fitted. The resulted equations are shown in Fig. 1.

Leaf nutrient content: The data shows in Table 8 and 9 clearly indicate that application of sewage sludge increased the cucumber leaf elemental contents grown in sandy and calcareous soils. The data revealed that macronutrients (N, P and K), micronutrients (Fe, Mn, Cu and Zn) and heavy metals (Cd and Ni) content increased gradually with increasing levels of sludge application. Also, sewage sludge insignificantly increased the contents of Ca, Mg and Co of cucumber leaves grown in sandy soil (Table 9). Also, the results in Table 9 showed that the concentration of N, P, Ca, Mg, Fe, Mn, Cu, Zn, Cd and Ni in cucumber leaves grown in calcareous soil significantly increased with increasing sewage sludge application rates. Also, sewage sludge insignificantly increased the content of K and Co of cucumber leaves grown in calcareous soils. Also, the data revealed that there was a positive significant correlation between application of sludge to the soil and cucumber leaf elemental contents (N, P, K, Ca, Mg, Fe, Mn, Cu, Zn, Cd, Co and Ni). The correlation coefficients were 0.99, 0.98, 0.99 0.97, 0.95, 0.97, 0.92, 0.98, 0.97, 0.96, 0.97 and 0.94, respectively for sandy soil. The corresponding values for calcareous soil were 0.99, 0.96, 0.82, 0.96, 0.77, 0.98, 0.86, 0.97, 0.98, 0.96, 0.99 and 0.98, respectively. Also, the data showed that there were a positive significant correlation between micronutrients content of sandy soil (Fe, Mn, Cu, Zn, Cd, Co and Ni) and leaves mineral contents (Fe, Mn, Cu, Zn, Cd, Co and Ni) of cucumber grown in sandy soil. The correlation coefficients were 0.96, 0.92, 0.84, 0.99, 0.96, 0.94 and 0.93, respectively. The corresponding values for micronutrients content (Fe, Mn, Cu, Zn, Cd, Co and Ni) of calcareous soil and leaves mineral contents of cucumber grown in calcareous soil were 0.77, 0.98, 0.76, 0.95, 0.87, 0.97 and 0.98, respectively.

Table 10: The impact of sludge application rates on elemental contents of cucumber fruits grown in sandy soil

Applied sludge ($t\ ha^{-1}$)	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Cd	Co	Ni
	(%)					($mg\ kg^{-1}$)						
0	1.250	0.400	1.545	0.411	0.091	37.6	9.1	5.0	7.3	0.122	0.126	0.168
25	1.620	0.514	1.579	0.411	0.100	40.0	9.2	5.6	14.2	0.149	0.131	0.266
50	1.750	0.524	1.894	0.42	0.112	40.4	10.3	7.1	29.3	0.154	0.139	0.275
75	1.830	0.570	1.923	0.432	0.114	46.8	10.4	7.6	29.5	0.176	0.148	0.305
100	2.110	0.602	2.087	0.449	0.114	47.5	10.7	7.7	30.6	0.178	0.165	0.382
125	2.310	0.612	2.439	0.496	0.126	48.6	10.8	8.1	30.8	0.199	0.171	0.395
LSD (0.05)	0.22**	0.05**	0.21**	0.03**	0.004**	2.60**	0.30**	0.44**	0.49**	NS	0.03**	0.03**

Table 11: The impact of sludge application rates on elemental contents of cucumber fruits grown in calcareous soil

Applied sludge ($t\ ha^{-1}$)	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Cd	Co	Ni
	(%)					($mg\ kg^{-1}$)						
0	1.310	0.305	1.598	0.402	0.113	33.1	10.0	5.9	20.4	0.108	0.112	0.316
25	1.760	0.420	1.689	0.410	0.125	34.9	11.3	6.5	28.6	0.114	0.123	0.354
50	1.890	0.480	1.827	0.417	0.128	36.5	12.2	6.8	29.1	0.169	0.136	0.368
75	2.050	0.560	1.929	0.418	0.131	37.3	12.4	7.0	29.7	0.178	0.144	0.376
100	2.250	0.651	2.003	0.429	0.141	38.2	14.1	7.3	31.1	0.185	0.163	0.389
125	2.360	0.743	2.168	0.442	0.159	39.9	14.9	8.3	34.8	0.188	0.178	0.429
LSD (0.05)	0.33**	0.04**	0.28**	NS	0.003**	NS	0.33**	0.52**	2.93**	0.03**	0.18**	0.05**

NS: Non significant; **Highly significant

Fruit nutrient content: Regarding the influence of sewage sludge applications on macronutrients (N, P, K, Ca and Mg), micronutrients (Fe, Mn, Cu and Zn) and heavy metals (Cd, Co and Ni) contents of cucumber fruit. The results presented in Table 10 clearly showed that the concentration of N, P, K, Ca, Mg, Fe, Mn, Cu, Zn, Co and Ni in cucumber fruits grown in sandy soil significantly increased with increasing sewage sludge application rates. Also, Cd content of fruit increased but insignificantly. The results in Table 11 showed that the concentration of N, P, K, Mg, Mn, Cu, Zn, Cd, Co and Ni in cucumber fruit grown in calcareous soil significantly increased with addition of sludge. While, Ca and Fe contents of fruit increased but insignificantly. Also, the data showed that there was a positive significant correlation between application of sludge and cucumber fruit elemental contents (N, P, K, Ca, Mg, Fe, Mn, Cu, Zn, Cd, Co and Ni). The correlation coefficients were 0.98, 0.94, 0.97, 0.91, 0.96, 0.96, 0.94, 0.95, 0.87, 0.98, 0.99 and 0.97, respectively for sandy soil. The corresponding values for cucumber fruits grown in calcareous soil were 0.97, 0.99, 0.99, 0.98, 0.96, 0.99, 0.99, 0.96, 0.90, 0.92, 0.99 and 0.97, respectively. Also, the data showed that there were a positive significant correlation between micronutrients content of sandy soil (Fe, Mn, Cu, Zn, Cd, Co and Ni) and fruits elemental contents (Fe, Mn, Cu, Zn, Cd, Co and Ni) of cucumber grown in sandy soil. The correlation coefficients were 0.83, 0.72, 0.80, 0.74, 0.95, 0.95 and 0.91, respectively. The corresponding values for micronutrients contents (Fe, Mn, Cu, Zn, Cd, Co and Ni) of calcareous soil and fruits elemental contents of cucumber grown in calcareous soil were 0.87, 0.92, 0.95, 0.77, 0.99, 0.96 and 0.94, respectively.

Such results may be due to application of sludge as a complexing agent, minimizes the loss of nutrients by leaching (Balba, 1973) and stimulates the biodegradation (composition) through increasing the population and activities of micro-organisms in soil (Mervat and Dahdoh, 1995). Decomposition of organic manures produces some organic acids such as fulvic, humic and carbonic acid that lower the soil pH values, which lead to solubilize soil nutrients and increases their availability and supply to plant uptake (Alexander, 1977; Dahdoh and El-Hassanin, 1993). Also, this results may be explained on the basis that the decomposition of sludge by microorganisms and subsequent release of their nutrients. Also, such increases in leaf nutrients content may be attributed to the increase of soil nutrients in the root zone and retained against leaching to deeper layer, in this case the nutrients become more available to plant uptake (Abd El-Naim *et al*., 1986).

The obtained results are in close agreement with those found by Elsokkary ***et al.*** (1989). They found that sewage sludge application increased the concentrations of P, K, Fe, Mn, Cu, Zn, Co, Ni, Pb and Cd in leaves and grain of alfalfa, wheat, faba bean and soybean. However, no visual symptoms of metal toxicity showed on the different plant species. Hussein (1991) reported that sludge application significantly increased the Ca, Mg, K, N, Fe, Mn, Cu and Zn in corn, sugar beet and cotton plants. Hussein and Abdel-Nasser (2001) found that macronutrients contents (N, P, K, Ca and Mg) and micronutrients contents (Fe, Mn, Cu and Zn) of sunflower leaves increased gradually with increasing levels of organic manure application. Antoline *et al.* (2005) found that N and heavy metals contents (Cd, Cr, Mn, Ni, Pd, Cu and Zn) in grain of barley increased as a result of addition of sludge. Recently, Mendoza *et al.* (2006) reported that the concentration of (Cu, Mn, Pb and Fe) increased in sorghum leaves grown in soil amended with sludge. Also, José de Melo *et al.* (2007) found that sewage sludge increased the metal content (Ni) in the maize shoots.

Referring to the nutrient criteria, cucumber plant contained sufficient P and K levels. The concentration of P in plants ordinarily ranges from 0.2 to 0.8% of the total dry matter (Walsh and Beaton, 1973). Also, the concentration of K in vegetative plant parts usually ranged between 1 and 3% of the dry tissue weight (Hausenbuiller, 1985). According to Hausenbuiller (1985), the concentration of N, Ca and Mg were within the normal ranges. The concentration of Mn in cucumber plants is within the normal range (15-100 mg kg^{-1}) (Hausenbuiller, 1985). The levels of Zn in the plants are much less than the general toxic limit (100 mg kg^{-1}) for plants given by Leeber (1972). The values of Cu concentration in the plants of cucumber were within the normal range found in plants (5-15 mg kg^{-1}) (Hausenbuiller, 1985). The concentration of Fe in the plants of cucumber is within the normal range found in plants (30-150 mg kg^{-1}) (Hausenbuiller, 1985). Typical amount of risk elements (Cd, Co and Ni) in plant are (0.1-1, 0.05-0.5 and 0.1-5 mg kg^{-1} for Cd, Co and Ni, respectively), (Vecera *et al.*, 1999). According to Vecera *et al.* (1999) the concentrations of Cd, Co and Ni in leaves and fruits of cucumber were within the normal range.

Growth and gross yield: The data presented in Table 12 show the effects of sludge application on the number of fruits and gross yield of cucumber plants. The data revealed that addition of sludge significantly increased the number of fruits and the gross yield of cucumber plants grown in sandy and calcareous soils. The number of fruits and gross yield of cucumber plants increased gradually as the application rate of sludge increased. The highest level of application has a highest effect on the growth and the yield of cucumber plants. The number of fruits increased by about 16.13, 22.58, 32.26, 41.94 and 45.16%, respectively for rates of 0, 25, 50, 75, 100 and 125 t ha^{-1} over the control treatment for cucumber plants grown in sandy soil. The corresponding values for calcareous soil were 11.11, 18.52, 29.63, 40.74 and 48.15%, respectively over the control treatment. Also, the gross yield of cucumber crop increased by about 23.28, 43.69, 54.30, 61.32 and 69.25%, respectively over the control treatment for sandy soil. The corresponding values for calcareous soil were 18.64, 32.26, 50.52, 75.18 and 85.51%, respectively over the control treatment. The data showed that there were a positive significant correlation between application of sludge and the number of fruits and yield of cucumber plants.

Table 12: Impact of sludge on the yield of cucumber grown in sandy and calcareous soils

Applied sludge (t ha^{-1})	No. of fruit/plot	Increase over control (%)	Gross yield (t ha^{-1})	Increase over control (%)
Sandy soil				
0	465	-	37.2	-
25	540	16.13	45.9	23.28
50	570	22.58	53.5	43.69
75	615	32.26	57.5	54.30
100	660	41.94	60.1	61.32
125	675	45.16	63.0	69.25
LSD (0.05)	7.14**		4.98**	
Calcareous soil				
0	405	-	30.5	-
25	450	11.11	36.2	18.64
50	480	18.52	40.3	32.26
75	525	29.63	45.9	50.52
100	570	40.74	53.4	75.18
125	600	48.15	56.55	85.51
LSD (0.05)	4.80**		8.90**	

The increase in cucumber production (no. of fruits and gross yield) due to sludge application are due to the effects of sludge on: (i) Improving soil aggregation, (ii) Increasing the soil water retention through its effect on pore-size distribution (water holding pores), Abdel-Nasser and Harhash (2000), (iii) Contribution of organic matter to the chemical properties and nutritional status of soil, such as lowering soil pH which lead to solubilization of soil nutrients and increases their availability and supply to plant uptake (Dahdoh and El-Hassanin, 1993) and (iv) Organic matter as a complexing agent, minimizes the loss of soil nutrients by leaching out of the root zone.

Organic manures are also considered as source of essential nutrients for plant growth (Chen and Avnimelech, 1986). Many investigators, Abdel-Naim *et al.* (1986) with maize, Abdel-Aziz *et al.* (1996) with sunflower and Abdel-Nasser and Harhash (2000) with grapevine showed the effect of soil conditioners on yield. They found a successive increase in the yields with increasing the rates of farmyard manure. Hussein and Abdel- Nasser (2001) found that application of different types of organic manures significantly increased the growth (fresh weight, disk weight and disk diameter) and the yield (seed yield, weight of 100 seeds, oil seed percent and oil yield) of sunflower. Soil properties such as plow layer thickness, organic matter and clay content affect crop productivity (Diaz-zorita *et al.*, 1999).

These results are in harmony with those obtained by Elsokkary *et al.* (1989). They found that sewage sludge application increased the dry weight and grain yield of alfalfa, wheat, faba bean and soybean. Zaid (1989) reported that yield of corn increased in sandy soil and calcareous soils as sewage sludge rate increased. Many studies appeared that adding sludge to the soil promotes plant growth significantly more than when commercial fertilizer is added. Christodoulakis and Margaris (1996) showed that plant height increased in maize individuals by 77% in the sludge amended treatment compared to 25% in the case of the commercial fertilizer amendment. Antoline *et al.* (2005) reported that application of sewage sludge increased the yield of barley grains. The higher yields in sludge-treated crops are usually attributed to an improvement in the soil conditions, by the supply of additional C from the sludge (Christie *et al.*, 2001). Also, the data showed that as mentioned before there were strongly correlated between application of sludge and the yield of cucumber crop (r = 0.97 for fruits grown in sandy soil and r = 0.98 for fruits grown in calcareous soil). These data suggest that sewage sludge application might induce a superior performance of cucumber crop by improving early seedling establishment (Badaruddin *et al.*, 1999).Wanderley *et al.* (2007) found that the grain production of maize increased in the presence of sewage sludge. This increase in grain production may be explained by the improvement in soil properties due to the OM and plant nutrients present in sewage sludge (Melo *et al.*, 2002).

CONCLUSION

Application of sewage sludge by mixing it with top 30 cm soil layer was found to be more effective in improving soil physical, chemical and fertility conditions of the soil. Moreover, using of sewage sludge as organic manure is considered as a source of nutrients that required for plant which led at the end to increase the growth and the yield of cucumber.

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