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# INFLUENCE OF SEWAGE SLUDGE AND BACTERIAL INOCULATION ON CORN PLANTS CULTIVATED IN NEWLY RECLAMED SOIL.

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## ABSTRACT

Field experiment was carried out in sandy loam soil at El-Tahrir province to evaluate the potentiality of utilization the municipal sewage sludge (applied at rates zero, 10 and 20 ton/fed.) with and without bacterial inoculation (*Bacillus polymyxa*) as a bio-organic fertilizer for corn plants under three levels of mineral N- fertilizer (zero, 60 and 120 Kg N/ fad.). Also, the effects of bio-organic materials as soil conditioner were considered.

The results showed significant increases in vegetative growth of corn plants due to three kinds of fertilizers. Moreover, either nitrogen fertilizer or bacterial inoculation had no effects on heavy metals content in corn plants. On the other hand, corn plants accumulated significant concentrations from heavy metals with increasing the sludge levels from zero to 10 and 20 ton / fed. Concerning the corn yield, the application of sewage sludge at levels 10 and 20 ton / fed increased the grain yield of corn by 37.3 and 56.3%, respectively over control. The addition of 60 and 120 Kg N / fed led to increase the grain yield by 60.5 and 101.7%, respectively over control. Moreover, the highest grain yield of corn was obtained in case of application of 20 ton sludge and 120 kg N / fed. Data also indicated that sewage sludge enhanced the some chemical and biological properties of soil namely organic matter, total-N, dehydrogenase activity and total count of bacteria. Also, addition of sewage sludge led to increase the DTPA extractable Cd, Pb and Ni in soil after corn harvesting.

**Keywords**: Sewage sludge, *Bacillus polymyxa*, Corn plants and reclaimed soil,

## INTRODUCTION

Sewage sludge is the solid wastes accumulated during primary, secondary and tertiary waste water treatment. Disposal or utilization of sewage sludge and municipal refuse is a major problem for most Cities. Ocean or sea dumping, land fills, and incineration are increasingly viewed as unsuitable alternatives for these wastes. Application of appropriately treated materials to agricultural lands, however, has frequently been demonstrated to be a safe and effective means for recovery of beneficial waste constituents (Page *et al.*, 1983 and Wei *et al.*, 1985). The primary factors to be considered when using sludges or sludge-based organic materials as fertilizer or soil amendments have concerned in several studies (Chaney, 1983; King, 1986; Chaney, 1989, Sims, 1990, Gardiner *et al.*, 1995; Mench, 1998).

Injurious constituents in sewage sludge that may hampered their agricultural utilization are mainly heavy metals (e. g. Cd, Cr, Ni, Pb, Cu, Hg and As) and potentially toxic organic compounds (e. g. PCBs).

Heavy metals ions when present at a high levels in the environment, are adsorbed by roots and translocated to different plant parts, thereby leading to impaired metabolism and reduced growth and yield (Sheoran *et al.* 1990, Angle *et al.* 1993, Abdel-Sabour, 1997, Biomy, 2000 and Al-Kahal *et al.* 2001). However, the effect of heavy metals on plant growth and metal uptake in soil is affected by different factors such as soil, pH, cation exchange capacity, organic matter, redox potential, oxide content and microbial biomass (Alloway, 1995 and Mensh, 1998).

Any soil protection policy must be aim to protect soil for human health and as a natural resource. The need to protect consumers from chronic toxicity is scientific motive for setting guidelines on trace element concentration in food and feed (Mensh, 1998). The permissible concentrations of toxic metals in crops or acceptable levels added to soil have been debated. Chaney (1983) suggested maximum tolerable levels in forage for cattle to be 0.5 mg $kg^{-1}$ for Cd, 50 for Ni and 500 for Zn. In addition, the same author (1990) concluded that low metal sludges are extremely safe when used in agriculture as a fertilizer and soil conditioner source. He proposed maximum permitted metals in sludge, which called NOAEL (No Observed Adverse Effect Level). The more common permissible limits of heavy metals in sludge are reported by USEPA as USEPA-503 regulations (Alloway, 1995). Many investigators found that the soils high in metal ions, particularly, Cd, should be used only for production an non food crops or non leafy foods such as grains, fruits or nuts, because fruiting parts of plants usually contain lower metal concentration than vegetative parts (Bingham *et al.*, 1975; Keefer *et al.*, 1986; Chang *et al.*, 1987 and Jing and Logan, 1992).

The objectives of this study, therefor were to evaluate the potentiality utilizing the municipal treated sewage sludge and bacterial inoculation as bio-organic fertilizer and soil conditioner for corn plants cultivated in newly reclaimed soil.

## MATERILAS AND METHODS

***Field experiment:***

Field experiment was conducted in summer season (May 2001) at Al-Nagah valley in El-Tahrir Province Sector that represented the oldest reclaimed region in Egypt.

The experiment was designed as split-split design with four replicates. The main plots were untreated and treated with sewage sludge at three levels (zero, 10 and 20 ton/fed). The sub plots were uninoculated and inoculated with *Bacillus polymyxa* and the sub plots were received three levels of N-fertilizer, ammonium sulfate (zero, 60 and 120 kg/fed). Phosphate and potassium fertilizers were added as a recommended doses for corn. Corn seeds (*Zea mays*, cv. Hybrid single 10) were cultivated as recommended practice in such employed soil. Irrigation was done using sprinkle system. Corn plants were harvested after 60 and 120 days of cultivation to evaluate the vegetative growth and yield components, as well as their contents from N, Cd, Pb, and Ni.

**Soil sampling:**

Representative soil samples were collected from experiment site before cultivation, then will mixed and prepared for analysis the main physical and chemical properties (Table 1). In addition, soil samples were collected from each treatment after corn harvesting, then air dried and ground to pass through 2mm sieve and stored for analysis.

**Table (1): Some physical and chemical properties of soil.**

| Properties | Values |
|---|---|
| Sand % | 67.96 |
| Silt % | 26.80 |
| Clay % | 5.24 |
| Texture class | Sandy loam |
| CaCO3 | 4.2 |
| SP % | 44 |
| pH | 7.6 |
| EC (dS/m) | 0.33 |
| **Soluble cations and anions (meq/l)** | |
| $Ca^{++}$ | 1.70 |
| $Mg^{++}$ | 0.96 |
| $Na^{+}$ | 0.71 |
| $K^{+}$ | 0.20 |
| $CO_3^{--}$ | 0.00 |
| $HCO_3^{-}$ | 0.67 |
| $Cl^{-}$ | 0.79 |
| $SO_4^{--}$ | 2.11 |
| Total-N % | 0.033 |
| Organic-C % | 0.35 |
| Total-soluble-N (ppm) | 37 |
| DTPA- extractable-Fe (ppm) | 4.1 |
| DTPA- extractable-Mn (ppm) | 3.4 |
| DTPA- extractable-Zn (ppm) | 1.2 |
| DTPA- extractable-Cu (ppm) | 0.37 |

**Sewage sludge:**

Sewage sludge used in this experiment provided from Municipal Sewage Water Treatment Plant (El-Gabal El-Asfar, Qalubia governorate). Five representive samples of sludge were collected, air dried and ground to pass through 2 mm sieve and prepared for analysis. The main characteristics of sludge used and some world permissible limits of heavy metals are given in Table (2).

**Bacterial inoculant:**

Culture of *Bacillus polymyxa* ($1x10^9$ cells/ml), local isolated was added to solid carrier (vermiculite + peat moss) to prepare the inoculant. Seed inoculation was done before sowing using arabic gum solution as adhesive material. Inoculant was applied at rate of 600 g per 12 kg corn seeds.

**Table (2) :Some chemical and microbiological characteristics of used sewage sludge and max permitted concentrations.**

| Parameters | Used sludge | Max permitted concentration from heavy metals * |
|---|---|---|
| PH | 6.67 | — |
| EC dS/m | 4.40 | — |
| Total - N % | 2.31 | — |
| Organic – C % | 30.98 | — |
| C/N ratio | 13.41 | — |
| Total – P % | 1.05 | — |
| N- $NH^{4+}$ (ppm) | 1522.5 | — |
| N- $NO^{3-}$ (ppm) | 56.7 | — |
| Available – P (ppm) | 250 | — |
| DTPA- extractable-Fe (ppm) | 279 | — |
| DTPA- extractable-Mn (ppm) | 41.2 | — |
| DTPA- extractable-Zn (ppm) | 188.5 | — |
| DTPA- extractable-Cu (ppm) | 35 3 | — |
| Total – Fe (%) | 0.43 | — |
| Total – Mn (ppm) | 232.5 | — |
| Total – Zn (ppm) | 735.6 | 2800 |
| Total – Cu (ppm) | 289.7 | 1500 |
| Total – Pb (ppm) | 430 | 300 |
| Total – Cd (ppm) | 1.46 | 39 |
| Total – Ni (ppm) | 68 | 420 |
| Total – Co (ppm) | 6.3 | — |
| Total coliforms | $1.3 \times 10^6$ | |
| Fecal coliforms | $3 \times 10^5$ | |
| Salmonella and Shigella | $8 \times 10^3$ | |

* According to US Environmental Protection Agency Part 503 regulation for sewage sludge applied to land (C.F. Alloway, 1995).

## Analysis:

### Soil:

Physical and chemical analysis of experiment soil before sowing were measured according to Black *et al.* (1965). Soil samples from different treatments after corn harvesting were analyzed for pH, total-N, organic matter, dehydrogenase activity, total count of bacteria and DTPA extractable Cd, Pb and Ni according to Page *et al.* (1982).

**Sewage sludge:**

The main chemical characteristics of sewage sludge was determined according to Page *et al.* (1983) while the pathogens test was conducted according to American Public Health Association (APHA) (1989).

**Plant materials:**

The oven dried plant materials were wet digested using mixture from pure $HClO_4$ and $H_2SO_4$ at ratio 1:1 according to Jackson (1973). N-concentration in digested solution was determined by Microkjeldahl method (Page *et al.*, 1982) while Cd, Pb and Ni were measured by Atomic Absorption Spectrophotometer System. Crude protein content in grains and stalks of corn was calculation by multiplied of N-concentration by 6.25.

**Statistical analysis:**

The data of plant parameters were statistically analyzed according to Snedecor and Cochran (1980).

## RESULTS AND DISCUSSION

**Vegetative growth of corn plant:**

Data presented in Table (3) show the main effect of sewage sludge, N-fertilizer or bacterial inoculation (*B. polymyxa*) on vegetative growth and element contents of corn plants after 60 days of planting. It is apparent that the increases in the growth parameters for plant height dry matter and total N-content. This flourish growth and height N-accumulation in plant tissues resulted in sludge application is expected and reflect the prominent role of organic matter from used sludge (O.C, 30.98 and C/N ratio, 13.41) in establishment of suitable growth media for corn plants via improving the physical, chemical and biological properties of sandy soil, as well as, supplying the grown plants with essential nutrients (Lawson *et al.*,1995; Abdel-Sabour, 1997; Abdel-Wahab,1999; Biomy, 2000 and Al-Kahal *et al.*, 2001).

On the other hand, corn plants exhibited great response to applied N-fertilizer. This means that the applied rates of sludge can not compensate the N-requirements which supplied mineral N-fertilizers, in despite of suitable C/N ratio and high N-content of employed sludge (13.41 and 2.31, respectively). In this concern, Sims (1990) found that wheat plants which received composted sludge at rate 44 ton/ha and supplemented with 100 kg N exhibited N deficiency symptoms, reduced dry matter production and lower plant N-concentrations.

Concerning the main effect of bacterial inoculation, results showed that addition of *Bacillus polymyxa* to corn seeds led to significant increase of plant height, dry matter and total N-content in comparison to uninoculated treatments. In fact, plant growth promoting rhizobacteria such as ***B. polymyxa*** can benefit the growth plants through several mechanisms including production of phytohormones, which reflected by enhancing the plant growth and nitrogen fixation which reflected by superiority of inoculated corn plants as compared to uninoculated ones for accumulation higher N in their tissue (Alvarez *et al.*, 1995; Gutierrez *et al.*, 1996 and James, 2000).

Table (3): Main effects of sludge, nitrogen fertilizer or bacterial inoculation on *yield and heavy metals* content of corn.

| Treatment | Plant height (cm) | Shoot D.Wt (g) | Roots D.Wt (g) | N. content in shoots (mg) | N- content in roots (mg) | Pb conc. Inshoots (ppm) | Pb conc. in Roots (ppm) | Cd conc. inShoots (ppm) | Cd conc. inRoots (ppm) | Ni conc. inShoots (ppm) | Ni conc. in Roots (ppm) | N.content of leaves (%) | Cd conc. of Leaves (ppm) | Pb conc. of leaves (ppm) | Ni conc. of leaves (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main effects of sludge (S) | | | | | | | | | | | | | | | |
| Zero | 121.1 | 45.3 | 7.6 | 583.2 | 44.9 | 9.2 | 12.4 | 0.05 | 0.08 | 5.66 | 7.9 | 1.44 | 0.04 | 6.77 | 78.2 |
| 10 ton/fed | 134.3 | 61.7 | 10.9 | 938.2 | 71.9 | 31.2 | 43.0 | 1.02 | 1.02 | 26.49 | 31.6 | 1.59 | 0.68 | 30.81 | 405.6 |
| 20 ton/fed | 146.9 | 68.9 | 14.4 | 1094 | 110.5 | 50.4 | 60.5 | 1.48 | 1.93 | 45.43 | 55.5 | 1.73 | 1.34 | 45.74 | 610.4 |
| L.S.D.0.05 | 8.3 | 9.2 | 0.38 | 106.9 | 3.47 | 1.60 | 5.94 | 0.15 | 0.02 | 3.39 | 1.95 | 0.05 | 0.19 | 2.72 | 3.62 |
| *Main effects fertilizer (N)* | | | | | | | | | | | | | | | |
| Zero | 115.3 | 31.4 | 8.7 | 338.3 | 51.6 | 30.2 | 39.4 | 0.8 | 0.99 | 26.3 | 31.8 | 1.4 | 0.66 | 28.36 | 354.0 |
| 60 kg N /fed | 136.4 | 64.3 | 11.6 | 939.8 | 77.6 | 30.5 | 37.6 | 0.8 | 1.03 | 25.4 | 31.9 | 1.6 | 0.71 | 27.24 | 367.7 |
| 120 kg N /fed | 150.6 | 80.2 | 12.7 | 1339 | 98.2 | 30.1 | 38.9 | 0.9 | 1.01 | 25.8 | 31.4 | 1.8 | 0.69 | 27.72 | 372.5 |
| L.S.D.0.05 | 8.19 | 6.3 | 1.17 | 105.3 | 8.9 | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | 0.08 | N.S. | N.S. | N.S. |
| Main effects of inoculation (I) | | | | | | | | | | | | | | | |
| Control | 126.4 | 55.8 | 10.6 | 817.4 | 72.7 | 30.2 | 38.0 | 0.9 | 1.01 | 25.3 | 31.8 | 1.6 | 0.68 | 27.35 | 545.5 |
| Uninoculated | 141.8 | 61.4 | 11.3 | 927.9 | 78.9 | 30.4 | 39.2 | 0.8 | 1.01 | 26.5 | 31.6 | 1.6 | 0.69 | 28.17 | 548.7 |
| L.S.D.0.05 | 8.7 | 4.3 | N.S. | 65.2 | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |

In respect of heavy metals content, data revealed that either N-fertilizer or bacterial inoculation had no effects on heavy metals content in corn plants. These finding are in accordance with Oliver *et al.* (1993) and Mench (1998). On the other hand, results displayed that corn plants grown on sludge treated plots accumulated significant concentrations from Cd, Pb and Ni in their tissues. It is clear that the maximum concentration of heavy metals in plant parts were obtained with application of sludge at rate of 20 ton/fed , but no visual symptoms of metal toxicity were observed. This means that the obtained extents of these metals are still lesser than critical levels which leading to incidence phytotoxicity (Alloway, 1995). However, the effects of these accumulated heavy metals on corn product consumers either human or animal should be taken in consideration. In addition, corn may cultivate in intensive wise as green forage in wide regions in Egypt, hence presence such as metals may be caused chronic toxicity for grazing animals.

It is worth to mention that corn plants grown on untreated plots accumulated heavy metals in their tissues. Phosphate fertilizers that contain appreciable content of heavy metals, particularly, Cd may be responsible for pollution with such metals (Alloway, 1995 and Mench, 1998). In addition, traditional manures such as farmyard manure which applied in great quantities to soil used may be the other reason for occurrence of pollution with heavy metals in untreated plots (Jones *et al.*, 1991; Johnston and Jomes, 1992 and Alloway, 1995).

Interactions between sludge, N-fertilizer and bacterial inoculation and their effects on vegetative growth and elements content are given in Table (4). Data showed that the joint application of 20 ton of sewage sludge, 120kg N/fed and bacterial inoculation recorded the highest values of vegetative growth parameters. Concerning the heavy metals content, results displayed that their contents of Cd, Pb and Ni in plant parts were gradually increased with increasing applied rate of sewage sludge irrespective of N-level or bacterial inoculation. In addition, the values of heavy metals concentrations in plant parts have non-significant differences among the same sludge rate, while the significant value was recorded between the treatments in any sludge level and those in other level.

**Yield components of corn:**

Influence of sewage sludge, N-fertilizer or bacterial inoculation on corn yield components and their content from heavy metals are presented in Table (5). It is clear that increasing of applied sludge rate led to significant increase the grain and stalk yield, as well as, their protein content. The maximum yield of corn was obtained with the level of 20 ton/fed. For instance, the addition of sewage sludge at levels 10 and 20 ton/fed led to increase the grain yield of corn by 37.3 and 56.3 %, respectively over the untreated treatment

The highest corn yield component resulted in sludge application is clear reflection to suitable niche and healthy growth plants at vegetative stage. Similar findings were reported by several investigators for many plants manured with sewage sludge at suitable rates, 20 to 40 ton/fed (Gradiner *et al.*, 1995; Abdel-Sabour, 1997; El-Sokkary and Abdel Salam, 1998; Biomy, 2000 and Al-Kahal *et al.*, 2001).

**Table (4): Interaction effect of sludge levels, bacterial inoculation, N-fertilizer levels on some vegetative growth of corn plants.**

| Treatments | | Plant height (cm) | shoot D.Wt. (g/plant) | Total N-content (mg/plant) | Heavy metals concentration in shoot (ppm) | | | root D.Wt. (g/plant) | Total N-content of rool(mg/plant) | Heavy metals concentration in root (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Cd | Pb | Ni | | | Cd | Pb | Ni |
| **Zero ton swage sludge/fed** | | | | | | | | | | | | |
| *Uninoc | Zero N/fed | 94 1 | 23.05 | 203.0 | 0.049 | 9 63 | 5.9 | 5.19 | 27.9 | 0.074 | 11.8 | 8.0 |
| | 60 kg N/fed | 112.0 | 43.90 | 481.6 | 0.050 | 9.50 | 5.6 | 7.98 | 42.6 | 0.075 | 12.1 | 7.6 |
| | 120 kgN/fed | 125 7 | 67 55 | 1017.3 | 0.057 | 8.93 | 5.5 | 9.68 | 64.8 | 0.077 | 12.2 | 8.4 |
| **Inoc | Zero N/fed | 114.1 | 22.98 | 214.7 | 0.064 | 9.17 | 5.6 | 5.27 | 27.8 | 0.074 | 13.4 | 8.0 |
| | 60 kg N/fed | 130.0 | 44.15 | 493.4 | 0.059 | 9.07 | 5.5 | 8.05 | 44.1 | 0.077 | 11.0 | 8.5 |
| | 120 kg n/fed | 151.0 | 69.88 | 1089.7 | 0.048 | 8.03 | 5.7 | 9.53 | 62.5 | 0.075 | 13.5 | 7 2 |
| 10 ton swage sludge/fed | | | | | | | | | | | | |
| *Uninoc | Zero N/fed | 111.3 | 31 05 | 332.5 | 0.863 | 31.97 | 25.8 | 8.83 | 48.8 | 0.983 | 42.9 | 31.2 |
| | 60 kg n/fed | 135.1 | 63.22 | 987.5 | 0 797 | 32.10 | 25.4 | 10.63 | 68.4 | 1.027 | 41.4 | 31 9 |
| | 120 k xg n/fed | 143.0 | 78 14 | 1260.4 | 0.877 | 30.07 | 25.5 | 11.72 | 86.5 | 1.050 | 40.4 | 32.8 |
| **Inoc | Zero N/fed | 117.3 | 32.22 | 386.6 | 0.823 | 31.50 | 27.8 | 9 27 | 51.0 | 0.993 | 44.5 | 32.8 |
| | 60 kg n/fed | 141 2 | 79 63 | 1230.5 | 0 847 | 31.03 | 26.8 | 12.35 | 80.6 | 1.060 | 44.5 | 31.1 |
| | 120 kgn/fed | 157.5 | 85.64 | 1431.6 | 0.867 | 30.17 | 27.7 | 12.88 | 96.7 | 1.017 | 44.3 | 31.8 |
| 20 ton swage sludge/fed | | | | | | | | | | | | |
| *Uninoc | Zero N/fed | 125.4 | 37.07 | 423.0 | 1.507 | 48.23 | 47.1 | 11.22 | 72.4 | 1.903 | 60.3 | 55.3 |
| | 60 kg n/fed | 139.1 | 72.57 | 1133.2 | 1.530 | 50.13 | 43.9 | 14.62 | 109.6 | 1.943 | 58.6 | 56.2 |
| | 120 kg n/fed | 148.9 | 86 03 | 1517.8 | 1.473 | 50.63 | 42.8 | 15.73 | 133.0 | 1.937 | 62.5 | 54.5 |
| **Inoc | Zero N/fed | 129.3 | 41 89 | 469.8 | 1.453 | 50.73 | 45.8 | 12.20 | 81.6 | 1.930 | 60.4 | 55.3 |
| | 60 kg n/fed | 157.8 | 82.33 | 1312.1 | 1.427 | 50.73 | 45.6 | 15 72 | 120.5 | 1.967 | 56.8 | 56.0 |
| | 120 kgn/fed | 177.6 | 93.78 | 1722.8 | 1.507 | 52.03 | 47.5 | 16.62 | 145.6 | 1.910 | 61.2 | 55.3 |
| LSD at 0.05% | | 68.25 | 14.749 | 219.32 | 0.113 | 6.708 | 7 0 | 2.659 | 21 71 | 0.099 | 11.42 | 8.7 |

*Uninoc: Uninoculated    ** Inoc: Inoculated with *Bacillus polymyxa*

Table (5): Main effects of sludge, nitrogen fertilizer or bacterial inoculation on yield and heavy metals content of corn.

| Treatment | Grain yield (Kg/fed) | Stalks yield (Ton/fed) | Seed protein (%) | Stalk protein (%) | Pb.c.in grain(ppm) | Pb.conc.in stalk(ppm) | Cd conc. in grain (ppm) | Cd conc. in Stalk (ppm) | Ni conc. in grain(ppm) | Ni conc. in Stalk (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Main effects of fertilizer (S)** | | | | | | | | | | |
| Zero | 927.6 | 3.38 | 8.53 | 4.56 | 3.86 | 4.97 | 0.03 | 0.04 | 3.57 | 6.39 |
| 10 Ton/fed | 1273.2 | 4.29 | 9.35 | 5.24 | 18.25 | 22.48 | 0.41 | 0.48 | 13.96 | 19.56 |
| 20 Ton/fed | 1449.8 | 4.64 | 10.31 | 5.58 | 28.63 | 30.99 | 0.57 | 0.68 | 21.58 | 28.81 |
| L.S.D 0 05 | 86.1 | 0.25 | 0.50 | 0.16 | 2.68 | 2.09 | 0.05 | 0.06 | 2.08 | 2.06 |
| **Main effects of fertilizer (N)** | | | | | | | | | | |
| Zero | 790.7 | 2.79 | 8.17 | 4.41 | 16.54 | 19.82 | 0.34 | 0.39 | 13.14 | 18.01 |
| 60 kg N /fed | 1269.3 | 4.40 | 9.24 | 5.09 | 16.83 | 19.08 | 0.33 | 0.41 | 12.77 | 18.33 |
| 120 kg N /fed | 1590.6 | 5.11 | 10.77 | 5.89 | 17.41 | 19.54 | 0.35 | 0.39 | 13.21 | 18.43 |
| L.S D 0.05 | 74.4 | 0.23 | 0.47 | 0.29 | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| **Main effects of fertilizer (N)** | | | | | | | | | | |
| Uninoculated | 1197.8 | 3.99 | 9.33 | 5.08 | 17.00 | 19.44 | 0.35 | 0.41 | 13.34 | 18.39 |
| Inoculated | 1235.9 | 4.21 | 9.45 | 5.18 | 16.85 | 19.52 | 0.33 | 0.39 | 12.74 | 18.12 |
| L.S.D 0 05 | N.S. | 0.18 | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |

Regarding the main effect of N-fertilizer on yield component and protein content, results clearly displayed the high response of grain and stalk yields and their protein contents to N-fertilizer application. Addition of 60 and 120 kg N/fed tended to increase the grain yield to 60.5 and 101.7 %, respectively over control. These finding confirmed those obtained with vegetative stage. Moreover, the bacterial inoculation with *B. polymyxa* did not affect any component of corn yield else stalk yield. The non-significant effect of bacterial inoculation on yield components may be elucidated by increasing the available-N from N-fertilizer and sludge to the limit, which may, reduced the microbial efficiency.

Concerning the concentrations of heavy metals in grains and stalks of corn, results show that N-fertilizer or bacterial inoculation not affected heavy metal concentrations in yield corn components. Moreover, the concentrations of Cd, Pb and Ni in yield components of corn displayed significant increase with increasing sewage sludge rate applied.

Interactions between sludge, N-fertilizer and bacterial inoculation and their effects on yield components of corn are presented in Table (6). Data clarified that joint application of N-fertilizer with sewage sludge tended to significantly increase the yield components in comparison with control or individual application in both. The highest values of grain yield and protein content were recorded in case of addition of 120 kg N/fed and 20 ton sewage sludge. Regarding the heavy metals content, obtained results behaved the same trend obtained with vegetative growth parameters.

In fact, corn is one of the main important crops in all world regions, which represented the nutriential and technological crop for human and animal. Hence the presence of any pollutants such as heavy metals in corn grains should be take in consideration, particularly that corn common to be more tolerant of phytotoxic metals than most dicotyledonous plants (Mc Bride, 1995). This means that the corn plant may accumulate great amounts from heavy metals that may exceeded toxic levels for human and animal. The sludge used in this study considered low in metal contents according to USEPA 503 regulations (Alloway, 1995) with exception lead content (430 ppm, while permissible limit is 300 ppm). However, the concentration values obtained in corn grains reached to 0.57, 28.6 and 21.5 ppm for Cd, Pb and Ni, respectively. These values exceeds the permissible values for consumers and may led to chronic toxicity for human and animal, particularly when they consumed the grain products, where such metals tended to be more affinity with protein rather than other legends in plant such as starch and lipid (Kabata-Pendias and Pendias, 1992)

**Effects on some soil chemical and biological properties:**

The changes occurring in some soil characteristics after corn harvesting as affected by application of sewage sludge, bacterial inoculation and N-fertilizer are presented in Table (7). In general, there are no any effects on investigated parameters due to bacterial inoculation. N-fertilizer application led to slight increases in some soil properties (total-N, total count of bacteria and dehydrogenase activity), while, it has not clear effect on another's (pH, organic matter and DTPA extractable heavy metals).

Table (6): Interaction effect of sludge levels, bacterial inoculation, N-fertilizer levels on some yield components of corn.

| Treatments | | Grain yield(Kg/fed) | Stalks yield (Ton/fed ) | Crude protein in grain % | Crude protein in stalk % | Heavy metals concentration in grain (ppm) | | | Heavy metals concentration in root (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Cd | Pb | Ni | Cd | Pb | Ni |
| **Zero ton swage sludge/fed** | | | | | | | | | | | |
| *Uninoc | Zero N/fed | 420.0 | 2 010 | 7.47 | 3 98 | 0 030 | 4.3 | 3.5 | 0.037 | 5 4 | 6.3 |
| | 60 kg N/fed | 1031.3 | 3 370 | 8.21 | 4.45 | 0 033 | 4.0 | 3.7 | 0.040 | 5.1 | 6.7 |
| | | 1348 7 | 4.547 | 9.89 | 5.25 | 0.034 | 3.5 | 3.6 | 0.040 | 4.8 | 5.8 |
| **Inoc. | Zero N/fed | 413.7 | 2.147 | 7.37 | 3.92 | 0.031 | 3.8 | 3.6 | 0.036 | 4.9 | 6.1 |
| | 60 kg N/fed | 994.0 | 3.827 | 8 30 | 4.47 | 0.035 | 3.6 | 3.3 | 0.040 | 4 7 | 6.0 |
| | 120 kg N/fed | 1358.0 | 4.38 | 9 99 | 5.31 | 0.034 | 4.2 | 3.7 | 0.038 | 5 0 | 6.5 |
| **10 ton swage sludge/fed** | | | | | | | | | | | |
| *Uninoc | Zero N/fed | 826.0 | 2 433 | 8.12 | 4.42 | 0.433 | 17 1 | 15.0 | 0.497 | 23.4 | 18 9 |
| | 60 kgN/fed | 1367.3 | 4.760 | 9.09 | 5.10 | 0.383 | 20 1 | 13.4 | 0.513 | 20.2 | 19.0 |
| | 120 kg N/fed | 1586.7 | 5.400 | 10.59 | 6.04 | 0.437 | 17 1 | 15.2 | 0.537 | 23.3 | 20.8 |
| **Inoc. | Zero N/fed | 858.7 | 2 947 | 8.25 | 4.45 | 0 380 | 18.4 | 12.8 | 0 463 | 23.1 | 19.8 |
| | 60 kgN/fed | 1362.7 | 4.690 | 9 34 | 5 29 | 0.407 | 17.2 | 14.4 | 0 517 | 22.6 | 18.1 |
| | 120 kg N/fed | 1638.0 | 5.480 | 10.68 | 6.14 | 0.433 | 19 5 | 13.0 | 0.523 | 22.4 | 20 8 |
| **20 ton swage sludge/fed** | | | | | | | | | | | |
| *Unino | Zero N/fed | 1106 0 | 3.480 | 8 92 | 4.79 | 0.620 | 28.7 | 21.4 | 0.687 | 31 6 | 28.0 |
| | 60 kgN/fed | 1386.0 | 4.867 | 10 12 | 5.47 | 0.543 | 27.9 | 21.3 | 0.680 | 31.1 | 30.6 |
| | 120 kg N/fed | 1708.0 | 5.787 | 11.66 | 6.22 | 0.613 | 30.3 | 23 0 | 0.690 | 30.3 | 28.4 |
| **Inoc. | Zero N/fed | 1120 0 | 3.727 | 8.94 | 4.89 | 0.550 | 26.9 | 22.6 | 0.653 | 30.6 | 28.9 |
| | 60 kg N/fed | 1474.7 | 4.903 | 10.36 | 5 74 | 0.557 | 28.1 | 20.6 | 0.693 | 30.8 | 29.6 |
| | 120 kg N/fed | 1904.0 | 5 750 | 11.83 | 6.74 | 0 560 | 29.9 | 20 7 | 0.667 | 31.6 | 27 3 |
| LSD at 0 05% | | 156.8 | 0.288 | 1.15 | 0 66 | 0.097 | 5.5 | 5.1 | 0 1 | 5.6 | 5 0 |

*Uninoc: Uninoculated ** Inoc: Inoculated with *Bacillus polymyxa*

Table (7): Effects of sewage sludge, bacterial inoculation and N-fertilizer levels on some chemical and biologica properties of soil.

| Treatment | Inoculation with *Bacillus polymyxa* | | | | | | | | Uninoculated | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PH (1:2.5) | O.M | Total N (ppm) | DHA µgTPF/g soil | Log No. bacteria (cfu/g soil) | DTPA- extractable heavy metals (ppm) | | | pH (1:2.5) | O.M % | Total N (ppm) | DHA µgTPF/g soil | Log No bacteria (cfu/gsoil) | DTPA- extractable heavy metals (ppm) | | |
| | | | | | | Cd | Pb | Ni | | | | | | Cd | Pb | Ni |
| **Zero ton sludge/fed.** | | | | | | | | | | | | | | | | |
| **Zero N** | 7.62 | 0.74 | 395 | 8.7 | 5.96 | 0.029 | 0.91 | 0.67 | 7.66 | 0.84 | 390 | 9.7 | 6 01 | 0.031 | 0.81 | 0.66 |
| **60 KgN** | 7.68 | 0.79 | 410 | 10.6 | 6.18 | 0.021 | 0.42 | 0.55 | 7.57 | 0.77 | 406 | 9.8 | 6.12 | 0.034 | 0.78 | 0.64 |
| **120 Kg N** | 7.56 | 0.88 | 422 | 12.4 | 6.24 | 0.035 | 0.53 | 0.71 | 7.55 | 0.76 | 409 | 11.7 | 6 23 | 0.024 | 0.79 | 0.73 |
| **10 ton sludge/fed.** | | | | | | | | | | | | | | | | |
| **Zero N** | 7.50 | 1.62 | 635 | 11.5 | 7.10 | 0.082 | 3.15 | 2.80 | 7.41 | 1.60 | 620 | 12.0 | 7.10 | 0.093 | 2.73 | 2.61 |
| **60 KgN** | 7 46 | 1.58 | 640 | 13.9 | 7.13 | 0.077 | 2.90 | 3.91 | 7.43 | 1.65 | 623 | 13.6 | 7.15 | 0.075 | 4.36 | 2.94 |
| **120 Kg N** | 7.45 | 1.75 | 661 | 14.6 | 7.21 | 0.080 | 5.02 | 2.00 | 7.35 | 1.63 | 639 | 15.8 | 7.20 | 0.084 | 3.43 | 4.25 |
| **20 ton sludge/fed.** | | | | | | | | | | | | | | | | |
| **Zero N** | 7 33 | 2.27 | 695 | 17.5 | 7.16 | 0 130 | 6.44 | 3.94 | 7.36 | 2.18 | 690 | 18.3 | 7.17 | 0.100 | 7.32 | 3.82 |
| **60 KgN** | 7.30 | 2.22 | 714 | 21.1 | 7.26 | 0.190 | 5.67 | 5.12 | 7.29 | 2.25 | 719 | 19.9 | 7.25 | 0.240 | 6.00 | 5.70 |
| **120 Kg N** | 7.26 | 2.37 | 730 | 22.7 | 7.28 | 0.160 | 7.13 | 4.31 | 7.24 | 2.32 | 726 | 21.3 | 7.27 | 0.180 | 6.35 | 5.11 |

Regarding the sewage sludge all studied soil parameters displayed high response to sewage sludge addition. The total count of bacteria increased by more one exponent than control due to application of sewage sludge at rates 10 and 20 ton/fed, indicating to inhance the biological activity in soil. This emphasized by marked increasing of dehydrogenase enzyme activity, which is considered the good indicator to biological activity in soil. Similar findings were obtained by Serra-Wittling *et al.* (1995), Pascual *et al.* (1997) and Goyal *et al.* (1999).

Data in Table (7) revealed a great increase in the DTPA-extractable Cd, Pb and Ni with increasing the level of sewage sludge applied. These findings are in agreement with those obtained by McBride (1995), Abdel-Sabour (1997), EL-Sokkary and Abdel-Salam (1998), Ramachandron and Souze (1998) and Al-Kahal *et al.* (2001).

The accumulation of available Cd, Pb and Ni resulted in sewage sludge application indicating to rapped decomposition of applied sludge (C/N ratio = 13.4) in despite of the pH values still more than 7 and organic matter of soil increased by about two to three folds than control. However, the USEPA 503 regulations recommended that pH should maintained at 6.5 or higher for applied sludge and soil to achieved the sludge protection hypothesis introduced by Ryan and Chaney (1993) which assumed that sludge decomposition can perpetually heavy metals solubility at very low levels by long time application.

In fact, the sludge used in this study has narrow C/N ratio and the Egyptian soils have climate completely different from template regions. In addition, Egyptian soils are very poor in organic matter, as well as, the oxidation rate of any applied organic materials is very rapid until these have wide C/N ratio (Abdel-Malek, 1971 and Ishac *et al.*, 1984).

Therefore, the climate condition, complete analysis of soil and sludge and suitable plant for cultivation are very important items and they merit to take in consideration, when any policy is planned to use such polluted materials for agriculture.

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## تاثير حمأة المجارى والتلقيح البكتيرى على نباتات الـــذرة المنزرعـة فـــى ارض حديثة الاستصلاح

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أقيمت تجربة حقلية بأرض رملية بمديرية التحرير بغرض دراسة إمكانية الاستفادة مـن حمـأة المجـارى الناتجة من محطة معالجة مياه المجارى بالقاهرة حيث أضيفت الحماة بمعدل صفر،١٠،٢٠ طن / فدان فى وجود وعـدم وجود التلقيح البكتيرى باستخدام ميكروب *Bacillus polymyxa* كسماد حيوى عضوى لنباتات الذرة صنف هجين فردى ١٠ تحت ثلاث مستويات من السماد الأزوتى المعدنى ( صفر ، ٦٠ ، ١٢٠ كجم نيتروجين /فدان .

اشتملت الدراسة على تأثير هذه المواد العضوية الحيوية على بعـض الخصـائص الكيمائيـة والبيولوجيـة للأرض . ولقد أظهرت النتائج أن إضافة أى من هذه الأسمدة الثلاثة قد أدى إلى زيادة معنوية فى قياسات النمو الخضرى لنباتات الذرة ، و لم يكن هناك أى تأثير واضح لكل من السماد المعدنى أو التلقيح البكتيرى على محتوى نباتات الذرة من العناصر الثقيلة . ومن ناحية أخرى تراكمت كميات معنوية من هذه العناصر فى نباتات الذرة نتيجة إضافة المسـتويات المختلفة من حمأة المجارى ( ١٠ ، ٢٠ طن / فدان ). أدت إضافة حمأة المجارى بمعدلات ١٠ ، ٢٠ طن / فدان الـى زيادة محصول الحبوب بنسبة ٣٧,٣ ، ٥٦,٣ % على التوالى مقارنة بتجربة المقارنة . كذلك أدت إضافة السماد الأزوتى بمعدلات ٦٠ ، ١٢٠ كجم نيتروجين / فدان الى زيادة محصول حبوب الذرة بنسبة ٦٠,٥ ، ١٠١,٧ % مقارنة بمعاملـة المقارنة على التوالى . علاوة على ذلك كان أعلى محصول لحبوب الذرة فى حالة إضافة ٢٠ طن من حمأة المجارى مع ١٢٠كجم من السماد الأزوتى . أوضحت النتائج المتحصل عليها من هذه الدراسة أن إضافة حمأة المجـارى أدت الـى تحسين بعض خواص التربة التى انعكست بزيادة قيم المادة العضوية والأزوت الكلى ونشاط إنزيم الديهيدروجينيز والعدد الكلى للبكتيريا . كذلك أدت إضافة حمأة المجارى الى زيادة الكميات المستخلصة من التربة أو DTPA مـن عنـاصر الكادميوم والرصاص والنيكل بمحصاد الذرة .