RESULTS AND DISCUSSION

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4.1. The chemical characteristics of sewage sludge:

A dried sewage sludge was collected from Sewage Treatment plant at Abu-Rawash, Giza Governorate. Data of the chemical and bacteriological analyses of this sludge are presented in Table (2). Data show that the average values of pH and EC of the sewage sludge were 6.97 and 3.5 dSm^{-1} at 25 °C, respectively.

The results indicate that the sewage sludge had a high percentage of total organic matter (42.2 %) and high contents of NPK (2.18 %, 0.545 % and 0.434 %, respectively). Therefore, sewage sludge may be considered one of the most efficient organic fertilizers in agriculture. This is in agreement with the result of **Jimenez et al. (1986).**

The contents of Fe, Mn, Zn, Cu, Pb and Cd in sewage sludge are given in Table (2). Data show that available amounts of heavy metals (mg kg^{-1}) are in order: Fe (125.9) > Zn (22.5) > Mn (18.4) > Pb (14.6) > Cu (13.49) > Cd (0.02).

The total amounts of heavy metals (mg kg^{-1}) are in the order: Fe (19000) > Pb (423.3) > Zn (211.6) > Mn (144.6) > Cu (115.1) > Cd (8.66). Data show that sewage sludge contains high values of non-essential heavy metals such as Pb and Cd, but available values of these heavy metals were low (less than toxic levels). So, it can be used as an organic fertilizer especially in sandy soils. This is in agreement with the results of **Abdel-Naim et al. (1982)** and **Rabie et al. (1996).**

The results also show that the pathogenic bacteria were found in dried sewage sludge which contained 86×10^6 and 56×10^4 CFU g^{-1} dried matter for total ***Coliform*** and ***Salmonella & Shigella***, respectively, and 0.0 active nitrogenase.

The potential hazard associated with the disposal of sewage sludge are related to the presence of toxic metals **(Lester, 1981)**, parasites and pathogenic microorganisms and a high moisture content even when dewatered **(American British Consultants, 1989).**

4.2. Effect of sewage sludge application on soil pH in ecosystem rhizosphere:

Data illustrated in Figs. (1 and 2) show the effect of sewage sludge application to the studied soil on soil pH in the rhizosphere of corn and faba-bean plants.

The obtained results show, generally, that soil pH values decreased with increasing sewage sludge treatments as compared with the control (untreated with sewage sludge).

This results may be attributed to rapid decomposition of sewage sludge and consequently higher production of both CO_2 and organic acids that would lead to reduction in pH values of soils treated with sewage sludge. These results are in agreement with those obtained by **Abdel-Naim et al. (1982),** and **Abou-Seeda (1987),** who reported that the pH values of the sandy soils of Egypt decreased from 8.2 to 7.1 due to sewage sludge application to soil.

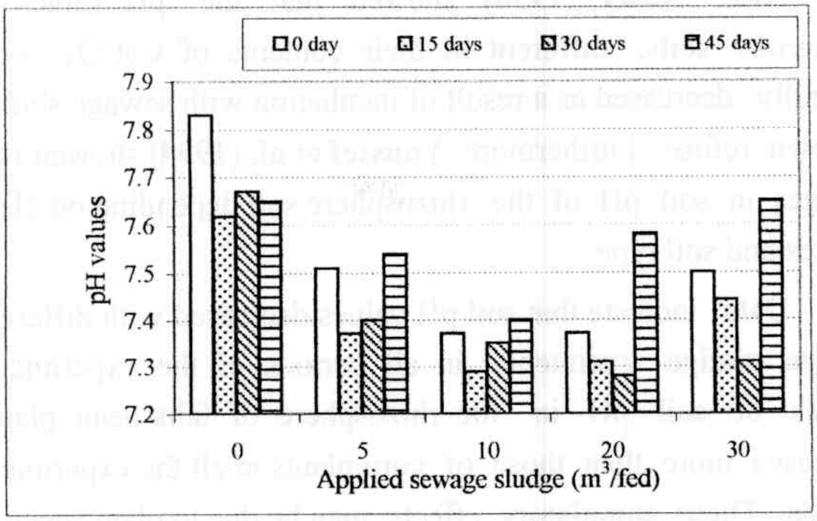

Fig. (1): Changes of soil pH in the rhizosphere of corn plants.

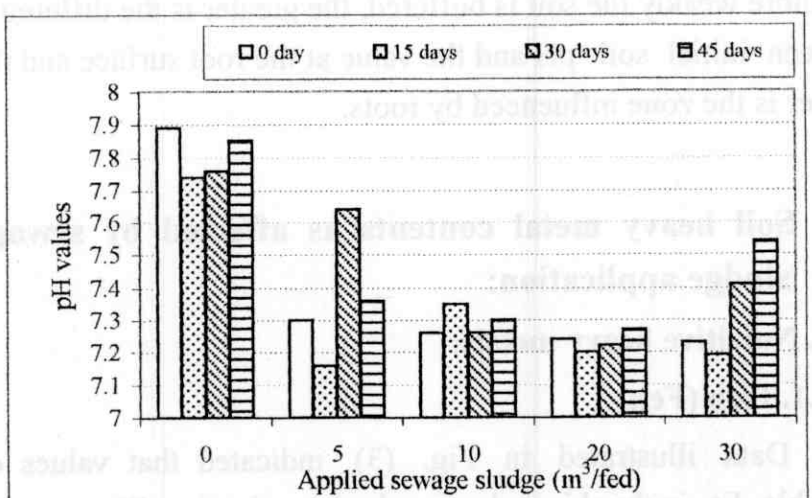

Fig. (2): Changes of soil pH in the rhizosphere of faba-bean plants.

Also, **Nasef (1996)** showed that the pH values of calcareous soils, different in their contents of $CaCO_3$, were generally decreased as a result of incubation with sewage sludge or town refuse. Furthermore, **Youssef et al. (1994)** showed that changes in soil pH of the rhizosphere soil depending on plant species and soil type.

Data indicate that soil pH values decreased with different sewage sludge treatments in all periods of the experiment. Values of soil pH in the rhizosphere of faba-bean plants decreased more than those of corn plants in all the experiment periods. These stimulatory effects may be due to plant species, the buffer capacity of the soil and its seasonal variations. The same trend was obtained by **Nye (1981), Schaller (1987)** and **Youssef and Chino (1989),** who reported that the changes of rhizosphere pH are restricted to a narrow zone around the root. The more weakly the soil is buffered, the greater is the difference between initial soil pH and the value at the root surface and the thicker is the zone influenced by roots.

4.3. Soil heavy metal contents as affected by sewage sludge application:

4.3.1. Nutritive heavy metals:

4.3.1.1. Iron (Fe):

Data illustrated in Fig. (3) indicated that values of available Fe in the rhizosphere under investigation. The average values of available Fe in the rhizosphere of corn plants were 2.3, 7.0, 18.3, 27.0 and 29.0 mg kg^{-1} and the corresponding values

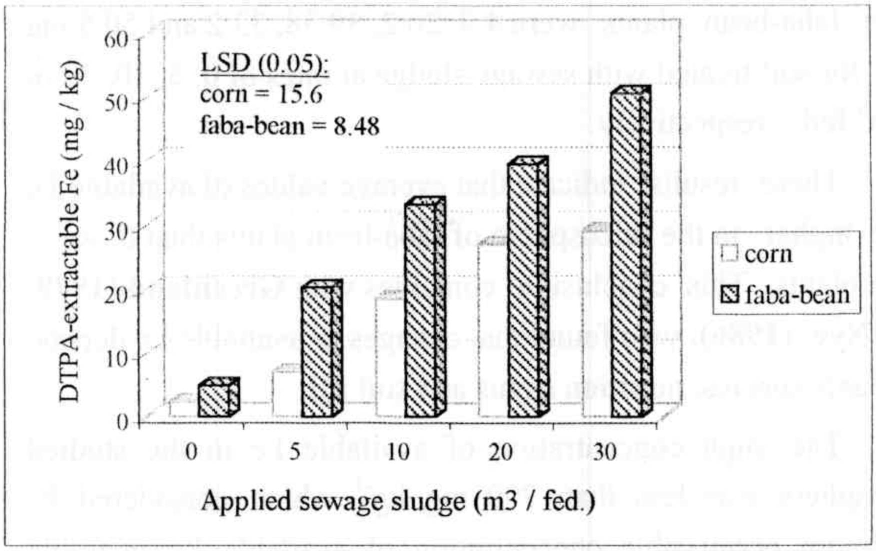

Fig. (3): DTPA-extractable Fe in rhizosphere of corn and faba-bean plants.

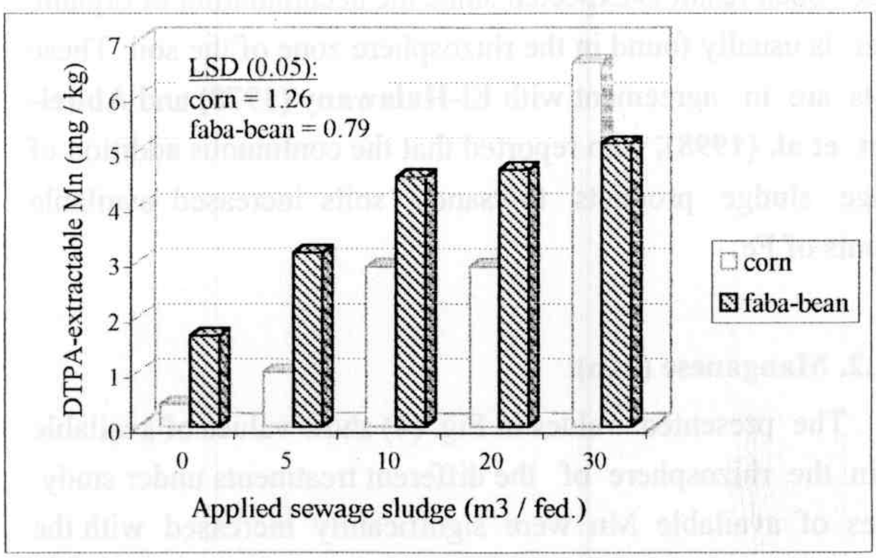

Fig. (4): DTPA-extractable Mn in rhizosphere of corn and faba-bean plants.

under faba-bean plants were 4.9, 20.2, 39.38, 33.2 and 50.5 mg kg^{-1} for soil treated with sewage sludge at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1}, respectively.

These results indicate that average values of available Fe were higher in the rhizosphere of faba-bean plants than those of corn plants. This conclusion coincides with **Greenland (1979)** and **Nye (1986),** who found that changes in available Fe depend on plants species, nutrition status and soil pH.

The high concentration of available Fe in the studied rhizosphere was less than 200 mg kg^{-1} which considered the maximum permissible concentration of available Fe in arable soil according to **National Academy of Science et al. (1972).**

Also results indicate that available Fe content was significant increased with increasing application of sewage sludge. Such result is expected since the accumulation of organic matter is usually found in the rhizosphere zone of the soil. These results are in agreement with **El-Halawany (1978)** and **Abdel-Naim et al. (1998),** who reported that the continuous addition of sewage sludge products to sandy soils increased available amounts of Fe.

4.3.1.2. Manganese (Mn):

The presented values in Fig. (4) show values of available Mn in the rhizosphere of the different treatments under study. Values of available Mn were significantly increased with the application rates of sewage sludge. The average values of available Mn in the soil treated with sewage sludge at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1} under corn plants were 0.4, 1.0, 2.9, 2.9 and 6.6 mg kg^{-1} and the corresponding values under faba-bean plants were 1.66, 3.16, 4.52, 4.65 and 5.12 mg kg^{-1}, respectively.

These increments of available Mn contents led to be employment sewage sludge as organic fertilizer. However, the highest concentration of available Mn due to sewage sludge treatments was still less than the maximum permissible Mn concentration (6.7 – 18.7 mg kg^{-1}) in Nile Delta soils, as mentioned by **Rashad et al. (1995).**

The average values of available Mn in rhizosphere soil samples under investigation were accompanied by an increase in sewage sludge treatments. These results are in agreement with those obtained by **El-Halawany (1978), Abdel -Naim et al. (1982)** and **Abd El-Aziz (1992).**

4.3.1.3. Zinc (Zn):

Data illustrated in Fig. (5) show values of available Zn in different treatments in the rhizosphere of corn and faba-bean plants.

Concerning the average values of available Zn in soil treated with sewage sludge at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1} under corn plants were 0.96, 2.6, 5.4, 6.8 and 7.06 mg kg^{-1}, and the corresponding values under faba-bean plants were 1.36, 6.56, 17.8, 20.6 and 20.7 mg kg^{-1}, respectively.

However, the highest concentrations of available Zn in all the treatments were less than the maximum concentration (200

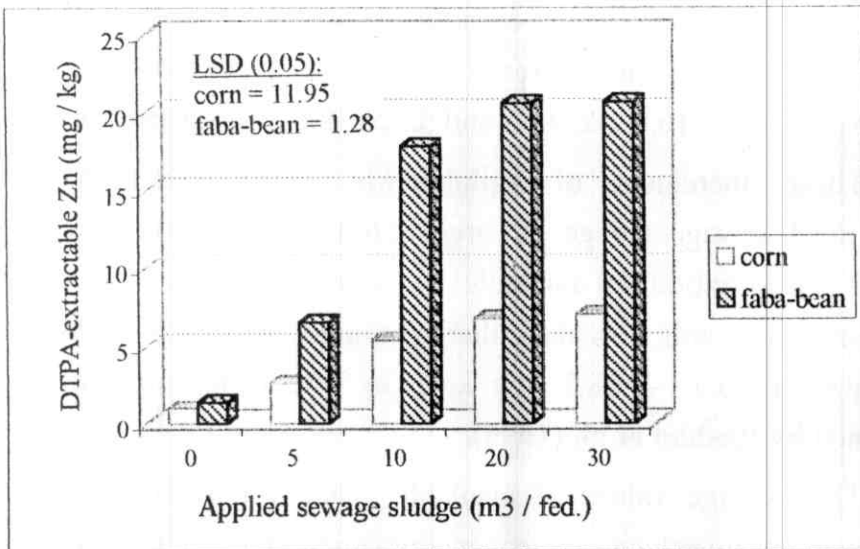

Fig. (5): DTPA-extractable Zn in rhizosphere of corn and faba-bean plants.

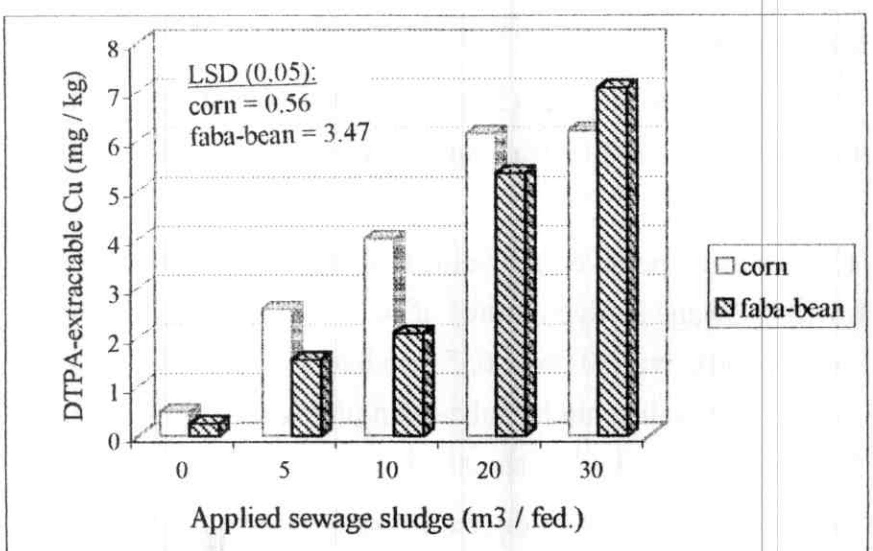

Fig. (6): DTPA-extractable Cu in rhizosphere of corn and faba-bean plants.

mg kg^{-1}) which reported as harmful for growing plants according to **National Academy of Science et al. (1972).**

Data indicate that available Zn significantly increased with increasing sewage sludge rates added to the soil. These results are in agreement with those obtained by **El-Sokkary and Lag (1978)** and **El-Gamal (1980).**

4.3.1.4. Copper (Cu):

Data illustrated in Fig. (6) show that average values of available Cu in the rhizosphere soil treated with sewage sludge at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1} were 0.5, 2.58, 4.0, 6.14 and 6.2 mg kg^{-1} under corn plants, and the corresponding values were 0.26, 1.55, 2.08, 5.34 and 7.08 mg kg^{-1} under faba-bean plants, respectively.

These values varied from 0.5 to 6.14 mg kg^{-1} in the rhizosphere of corn plants, while it varied from 0.26 to 7.08 mg kg^{-1} in the rhizosphere of faba-bean plants. The highest concentration of available Cu in these soils never reach the maximum concentration (80 mg kg^{-1}), which may be considered harmful for growing plants, as mentioned by **National Academy of Science et al. (1972).**

The previous data reveal that available Cu accumulated mostly in the rhizosphere of the soil treated with sewage sludge at the rates of 5 m^3 fed^{-1} under corn plants. However, the corresponding values of rhizosphere under faba-bean plants grown in soils treated with sewage sludge at rates of 20 or 30 m^3 fed^{-1} were significantly higher than the other rates (0, 5 and 10

m^3 sewage sludge fed^{-1}). These results are in agreement with those obtained by **Abdel-Aal et al. (1991),** who found that soil content of available Cu was correlated positively and significantly with their contents of organic matter (r = 0.904).

Matter (1999) showed that increase in available Cu content with increasing time of irrigation by sewage water can not be attributed to the suspended organic matter applied to the soil only but also to the effect of the organic acids produced due to decomposition of organic matter on reducing soil pH.

4.3.2. Non-nutritive heavy metals:

4.3.2.1. Lead (Pb):

Data illustrated graphically in Fig. (7) show that the available values of Pb in the rhizosphere zone of the soil under investigation were highly significant increased with the application rates of sewage sludge. These increases were varied due to the application of sewage sludge. The average values of available Pb were 0.58, 5.2, 10.2, 11.4 and 11.7 mg kg^{-1} in the rhizosphere of corn plants and 1.01, 3.9, 10.6, 12.0 and 14.0 mg kg^{-1} in the rhizosphere of faba-bean plants, for soils treated with sewage sludge at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1}, respectively. The highest concentration of available Pb in the investigated soils in the rhizosphere soil was less than 40 mg kg^{-1} which reported as a maximum permissible limit for arable lands according to **National Academy of Science et al. (1972).**

Data indicate that available Pb increased with increasing sewage sludge rates applied to the soil. These results are in agreement with those obtained by **Ellis and Knezek (1972)** and

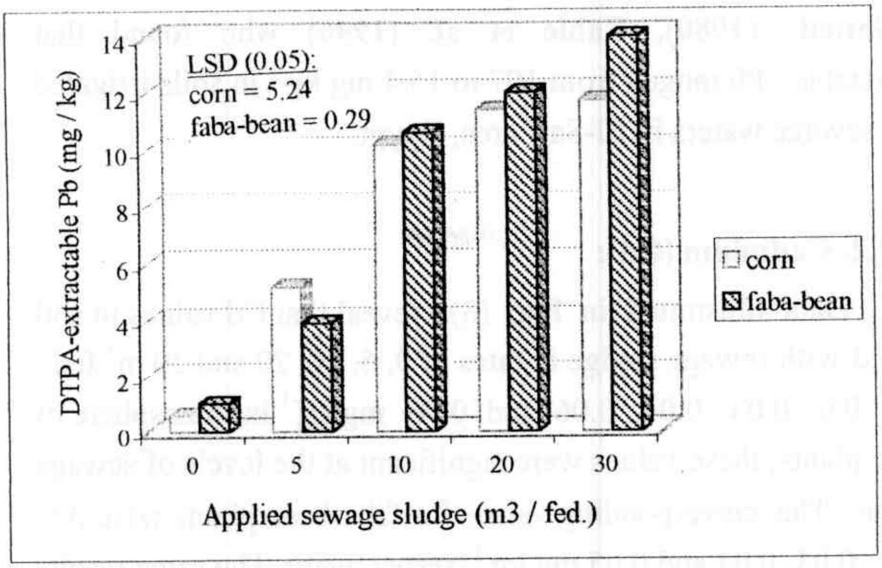

Fig. (7): DTPA-extractable Pb in rhizosphere of corn and faba-bean plants.

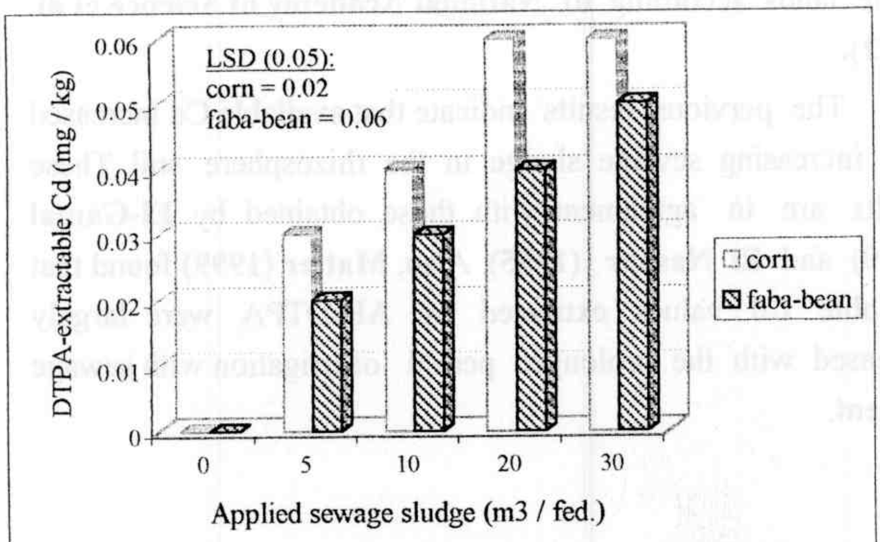

Fig. (8): DTPA-extractable Cd in rhizosphere of corn and faba-bean plants.

El-Gamal (1980). Rabie et al. (1996) who found that extractable Pb ranged from 107 to 15.4 mg kg^{-1} in soils irrigated with sewage waters in El-Saff area, Egypt.

4.3.2.2. Cadmium (Cd):

Data illustrated in Fig. (8), reveal that Cd values in soil treated with sewage sludge at rates of 0, 5, 10, 20 and 30 m^3 fed^{-1} were 0.0, 0.03, 0.04, 0.06 and 0.06 mg kg^{-1} in rhizosphere of corn plants; these values were significant at the levels of sewage sludge. The corresponding values for faba-bean plants were 0.0, 0.02, 0.03, 0.04 and 0.05 mg kg^{-1}, respectively. The same results were obtained by **Aboulroos et al. (1996).**

The highest concentration was less than 1.0 mg kg^{-1} which is considered the maximum concentration permissible for arable lands according to **National Academy of Science et al. (1972).**

The pervious results indicate that available Cd increased with increasing sewage sludge in the rhizosphere soil. These results are in agreement with those obtained by **El-Gamal (1980)** and **El Nashar (1985)**. Also, **Matter (1999)** found that available Cd values extracted by AB-DTPA were largely increased with the prolonged period of irrigation with sewage effluent.

4.4. Effect of sewage sludge application on biological activities in ecosystem rhizosphere:

4.4.1. CO_2 in soil (Soil respiration rate) as an indication for biological activity:

Data illustrated in Figs. (9 and 10) show the effect of sewage sludge treatments on biological activity in the rhizosphere soil as represented by CO_2 in soil. The mean values ranged from 3.66 to 28.26 and from 46 to 20.88 µg CO_2 g^{-1} dry soil / hour in the rhizosphere of corn and faba-bean plants, respectively.

Results of the two cultivation seasons of corn and faba-bean plants almostly showed the same trend.

These results illustrated by Figs (9 and 10) indicate that CO_2 evolved, generally, increased with increasing the rate of sewage sludge applied to soil. This increase reflects the enhancement of the biological activity in rhizosphere soil. In this respect, **Fawaz et al. (1976)** and **Abou El-Naga et al. (1982)** reported that microbial number and activity in the rhizosphere soil were correlated with organic manure content. In similar instance, **Panikov et al. (1982)** noted that addition of sewage sludge to soil increased CO_2 production in rhizosphere soil. The same results were obtained by **Kadhim (1986)** who mentioned that application of organic manures to old and virgin soils increased the total counts of bacteria and CO_2 in soil, as well as improving their biological and chemical properties.

Regardless the content of sewage sludge fertilization, treatments enhanced the bacterial growth (CO_2) in sandy soil according to the order, 30 m^3 fed^{-1} > 20 m^3 fed^{-1} > 10 m^3 fed^{-1} >

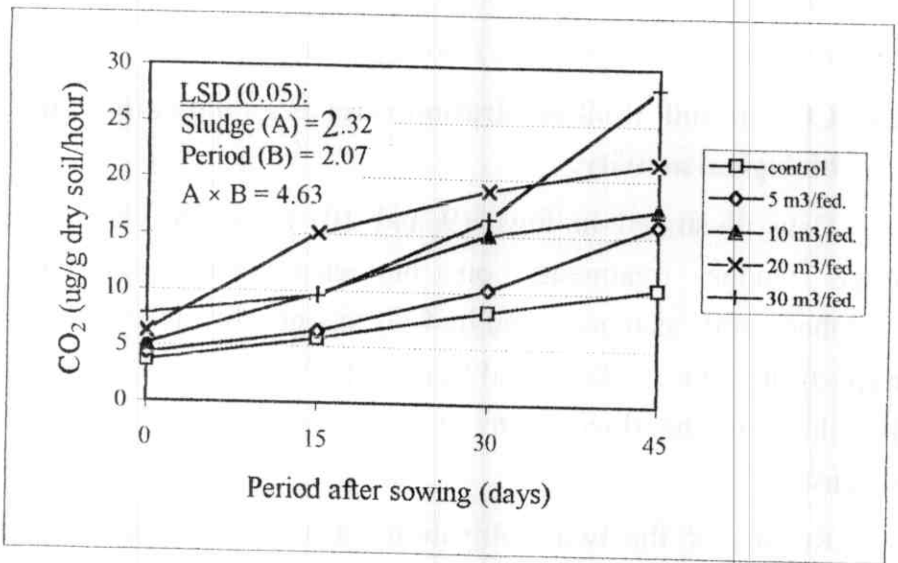

Fig. (9): Rates of respiration (CO_2) in the rhizosphere of corn plants

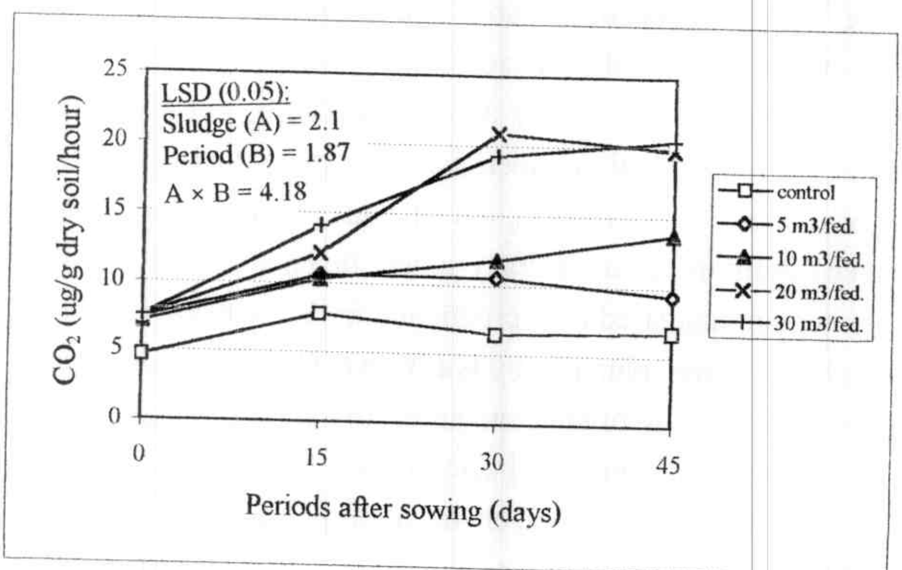

Fig. (10): Rates of respiration (CO_2) in the rhizosphere of corn plants

5 m^3 fed^{-1} > zero sewage sludge (control). These results are in agreement with those obtained by **Idnani and Varadargen (1974), Sathianathan (1975), Abd-El-Aziz et al. (1982), Alaa El-Din et al. (1984)** and **Mahmoud et al. (1992).**

The results also indicate that the biological activity in the rhizosphere soil, generally, increased during the growth period of corn plants, but it was decreased after 45 days from planting of faba-bean plants treated with sewage sludge at the rate of 5 or 20 m^3 fed^{-1}. These stimulatory effects may be due to differences of plant species grown and seasonal variation in these soils. In this respect, **Nye (1981)** and **Schaller (1987)** reported that the seasonal variation in soil organic matter contents were reflected the differences in the C concentration of organo-mineral particle size fractions.

4.4.2. Nitrogenase activity as an indicator for nitrogen fixation:

The results of nitrogenase activity in the different treatments are listed in Table (6) and illustrated graphically by Figs. (11 and 12). At the beginning of the experiment, the highest activity of nitrogen fixation was found in the rhizosphere of faba-bean plants (0.03 μ mol C_2H_4/Hr/g dry weight of soil) in comparison with this value in the rhizosphere of corn plants which was 0.002 μ mol C_2H_4/Hr/g dry weight of soil. The nitrogen fixation increased with increasing time of experiment at all rates of application of sewage sludge. These results are in agreement with those obtained by **Coppola et al. (1986).**

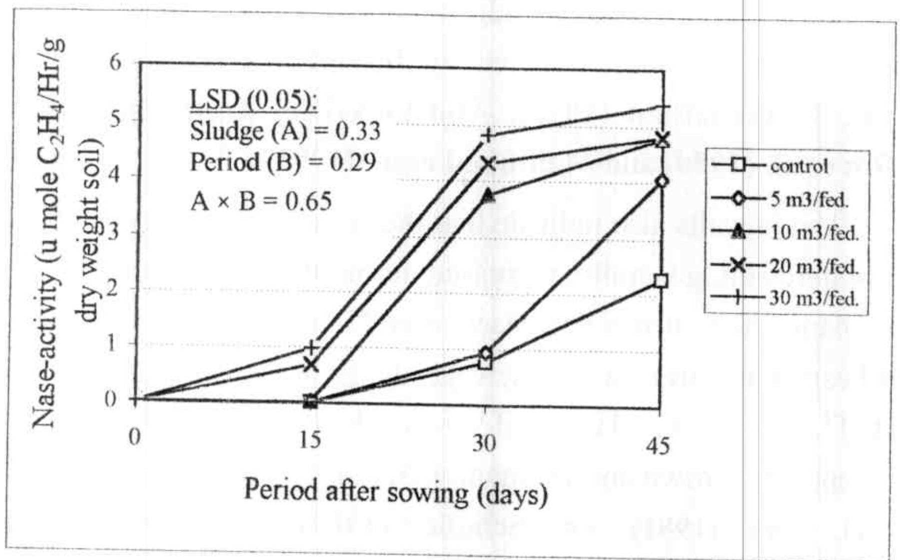

Fig. (11): Nitrogenase activity in the rhizosphere of corn plants

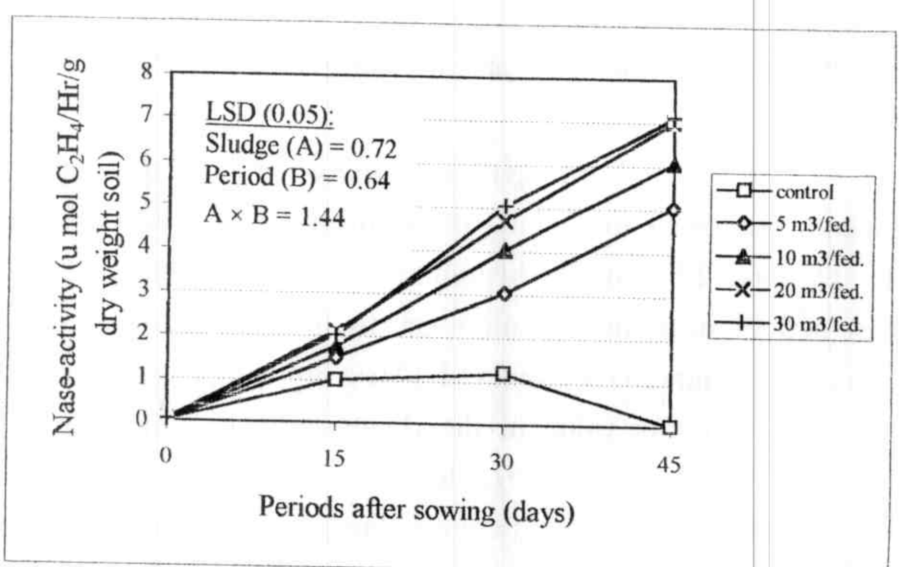

Fig. (12): Nitrogenase activity in the rhizosphere of faba-bean plants

The greatest quantities of fixed N_2 are contributed to agriculture by symbiotic N_2-fixation in legumes. This is of increasing importance as agricultural production in developed countries moves towards lower input, more extensive systems legumes and other non-leguminous N_2-fixing biosis also have an important rate to play in the regeneration of soil fertility on spoils system **(Skeffington and Bradshaw, 1980).**

With regard to the correlation between CO_2 and nitrogenase activity, it was highly significant ($r = 0.9$ and 0.7) for corn and faba-bean plants, respectively. The reason of CO_2 reduction in the rhizosphere under faba-bean plants than under corn plant was due to increasing microbial activity in faba-bean plants because of fixation of nitrogen air (bioassimilation energy) than in corn plants, that was the reason of microbial respiration increasing in corn's rhizosphere.

The following equation describes the relation. The rate of carbon dioxide output ($x = \mu g\ CO_2/g$ soil/h), and the nitrogenase activity ($y = \mu$ mol C_2H_4/Hr/g dry weight soil). In corn plant was ($x = 0.2889\ y - 1.564$) but in faba-bean plant was ($x = 0.3276\ y - 1.24$). These results are in agreement with **Antoun and Armanios (1990),** who found highly significant positive correlation ($r = 0.9621$) between microbial respiration and nitrogenase activity of soil treated with clover residues.

4.5. Effect of sewage sludge application on the counts of pathogenic bacteria:

Coliform*, *Salmonella* and *Shigella groups were used as indicators for the destruction of pathogenic bacteria in the sewage sludge.

4.5.1. Counts of *Coliform* group:

Data illustrated by Figs. (13 and 14) show the counts of ***Coliform*** group in the rhizosphere of corn and faba-bean of the different treatments under investigation. The average counts of ***Coliform*** group in the rhizosphere of corn plants fertilized with sewage sludge at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1} were n.d, 29, 34, 47 and 59 (10^4) CFU on dried material and in the rhizosphere of faba-bean plants were n.d, 18, 22, 50 and 65 (10^4) CFU g dried material, respectively, in the first period (at zero time of sowing).

The results indicate that the counts of ***Coliform*** group in the rhizosphere zone increased with increasing rate of sewage sludge application. Such results are expected since the accumulation of sewage sludge is usually found in the rhizosphere zone of the soil. These results are in agreement with **Niewolak and Szelagiewicz (1997),** who showed that the numbers of total ***Coliform*** in soils depended on the amount of sewage sludge used in fertilization.

Data also show that total counts of ***Coliform*** bacteria decreased rapidly by increasing the growing period of corn and faba-bean plants. Their numbers were, however, much higher than ***Salmonella*** and ***Shigella***.

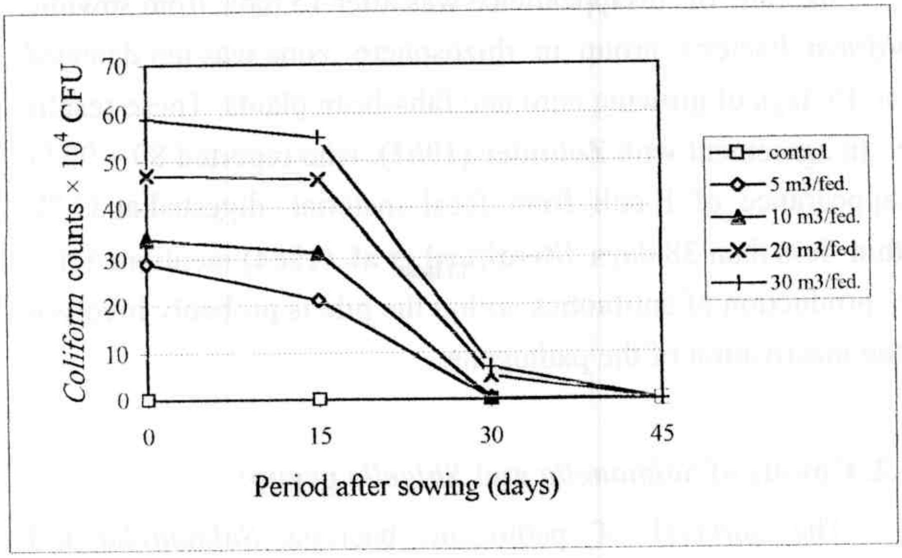

Fig. (13): Changes of *Coliform* group counts in the rhizosphere of corn plants

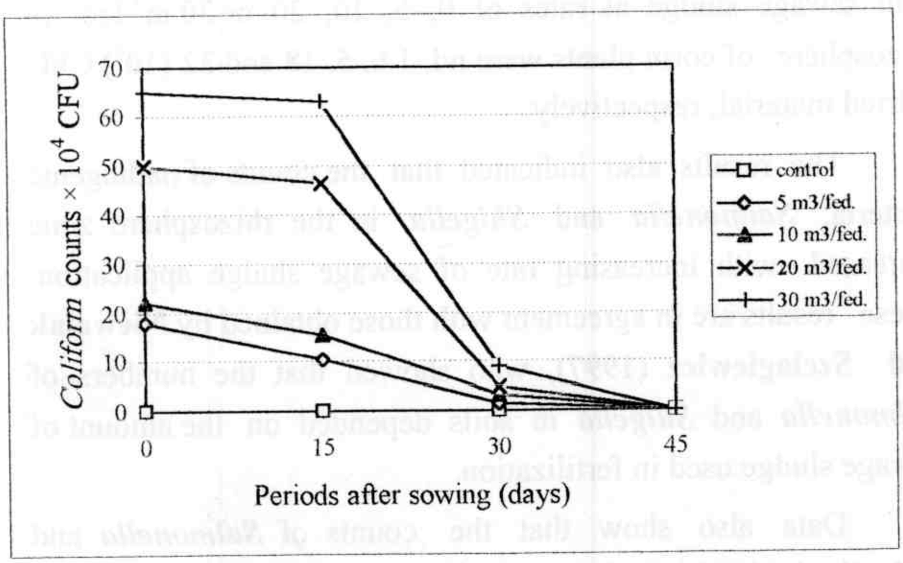

Fig. (14): Changes of *Coliform* group counts in the rhizosphere of faba-bean plants

Its rate of disappearance was after 15 days from sowing. *Coliform* bacteria group in rhizosphere zone was not detected after 45 days of growing corn and faba-bean plants. These results are in agreement with **Zehnder (1982),** who reported 80 – 99 % disappearance of E.coli from fecal material digested at 33 °C within less than 38 days. **Stentiford et al. (1984)** mentioned that the production of antibiotics within the pile is probably involved in the inactivation of the pathogens.

4.5.2. Counts of *Salmonella* and *Shigella* group:

The survival of pathogenic bacteria, ***Salmonella*** and ***Shigella***, are presented in Figs. (15 and 16).

The results indicate that at zero time of the sowing, the average counts of ***Salmonella*** and ***Shigella*** in the soil treated with sewage sludge at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1} in rhizosphere of corm plants were nd, 1.6, 5, 18 and 32 (10^4) CFU g dried material, respectively.

The results also indicated that the counts of pathogenic bacteria, ***Salmonella*** and ***Shigella*** in the rhizosphere zone increased with increasing rate of sewage sludge application. These results are in agreement with those obtained by **Niewolak and Szelagiewicz (1997),** who showed that the numbers of ***Salmonella*** and ***Shigella*** in soils depended on the amount of sewage sludge used in fertilization.

Data also show that the counts of ***Salmonella*** and ***Shigella*** in the rhizosphere zone decreased rapidly by increasing the growing period of corn and faba-bean plants. Its rate

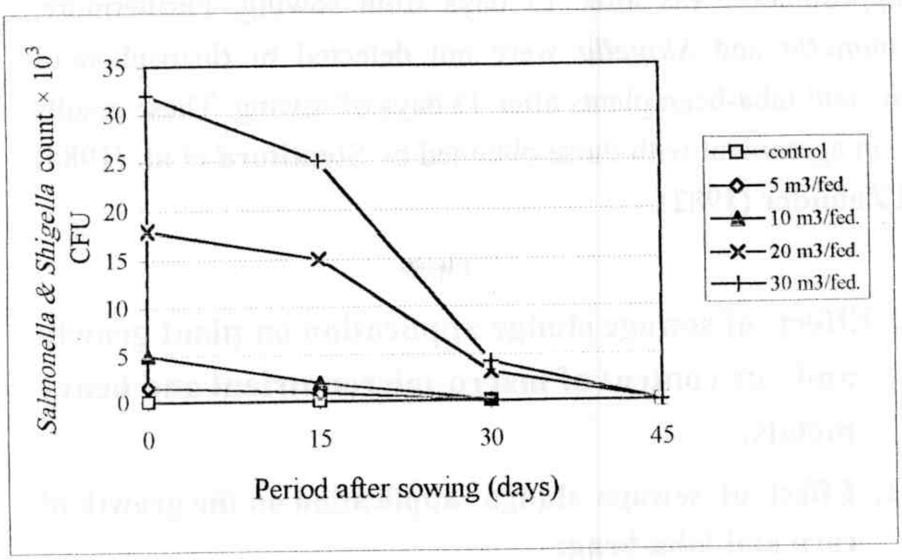

Fig. (15): Changes of *Salmonella* & *Shigella* counts in the rhizosphere of corn plants

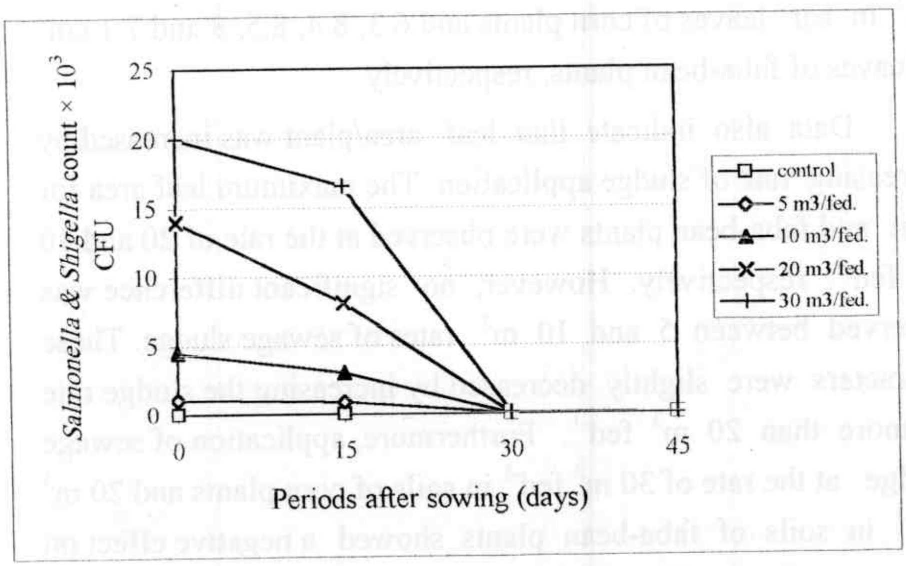

Fig. (16): Changes of *Salmonella* & *Shigella* counts in the rhizosphere of faba-bean plants disappearance was after 15 days from sowing. Furthermore, ***Salmonella*** and ***Shigella*** were not detected in rhizosphere of corn and faba-bean plants after 45 days of sowing. These results are in agreement with those obtained by **Stentiford et al. (1984)** and **Zehnder (1982).**

4.6. Effect of sewage sludge application on plant growth and its content of macro-micronutrient and heavy metals:

4.6.1. Effect of sewage sludge application on the growth of corn and faba-bean:

Data in Figs. (17 and 18) show that values of leaf area / plant grown in soil treated with sewage sludge at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1} were 469.8, 473.1, 556.8, 562.5 and 560 cm^2 in ear leaves of corn plants and 6.3, 8.4, 8.5, 8 and 7.1 cm^2 in leaves of faba-bean plants, respectively.

Data also indicate that leaf area/plant was increased by increasing rate of sludge application. The maximum leaf area for corn and faba-bean plants were observed at the rate of 20 and 10 m^3 fed^{-1}, respectively. However, no significant difference was observed between 5 and 10 m^3 rates of sewage sludge. These characters were slightly decreased by increasing the sludge rate to more than 20 m^3 fed^{-1}. Furthermore, application of sewage sludge at the rate of 30 m^3 fed^{-1} in soils of corn plants and 20 m^3 fed^{-1} in soils of faba-bean plants showed a negative effect on these parameters. The inhibited growth of corn and faba-bean plants caused by the higher rates of sewage sludge may be due to

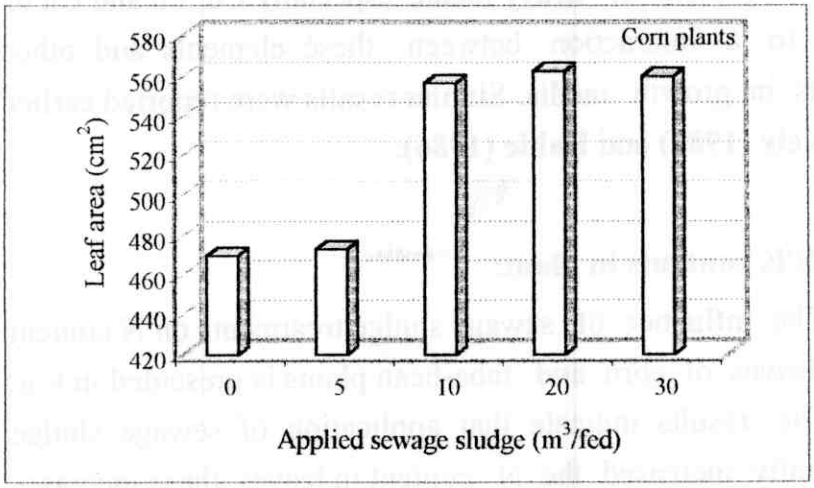

Fig. (17): Leaf area (cm^2) of corn plants grown in soil treated with sewage sludge..

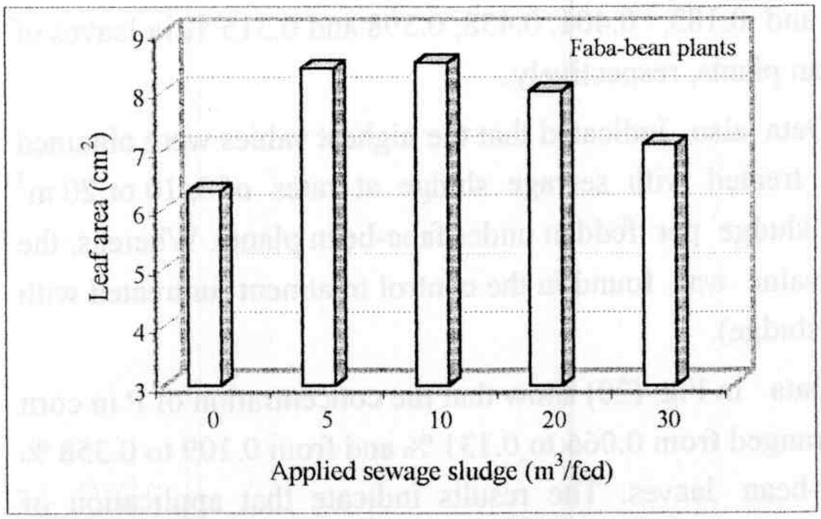

Fig. (18): Leaf area (cm^2) of faba-bean plants grown in soil treated with sewage sludge..

its higher content of heavy metals especially Cd, Pb and Cu or related to a interaction between these elements and other elements in growth media. Similar results were reported earlier by **El-Keiy (1983)** and **Rabie (1986).**

4.6.2. NPK contents in plant:

The influence of sewage sludge treatments on N content in ear leaves of corn and faba-bean plants is presented in Fig. (19). The results indicate that application of sewage sludge significantly increased the N content in leaves, these increases were highly increased by increasing the rate of sewage sludge application to soil.

The values of N % at rates of 0, 5, 10, 20 or 30 m^3 fed^{-1}, were 0.284, 0.356, 0.363, 0.392 and 0.332 % in leaves of corn plants, and 0.183, 0.401, 0.438, 0.398 and 0.315 % in leaves of faba-bean plants, respectively.

Data also indicated that the highest values were obtained in soils treated with sewage sludge at rates of 5, 10 or 20 m^3 sewage sludge per feddan under faba-bean plants. Whereas, the lowest value was found in the control treatment (untreated with sewage sludge).

Data in Fig. (20) show that the concentration of P in corn leaves ranged from 0.066 to 0.131 % and from 0.109 to 0.358 % in faba-bean leaves. The results indicate that application of sewage sludge significantly increased the P content in faba-bean leaves, except for the rate 30 m^3 fed^{-1}. These results are in agreement with those obtained by **Rabie et al. (1996),** who

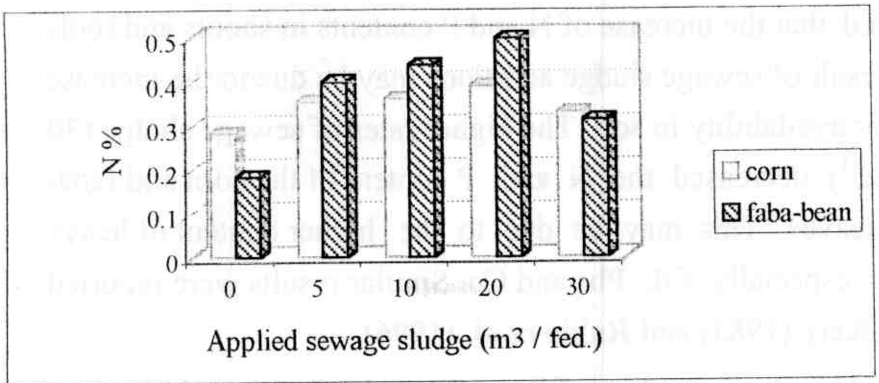

Fig. (19): Total N% in ear leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

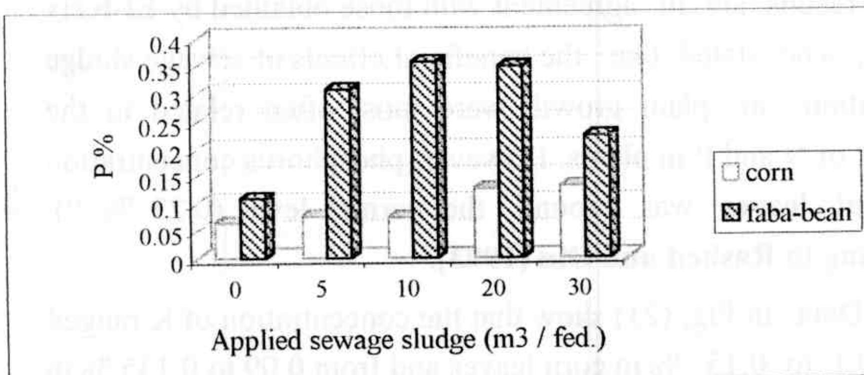

Fig. (20): Total P% in ear leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

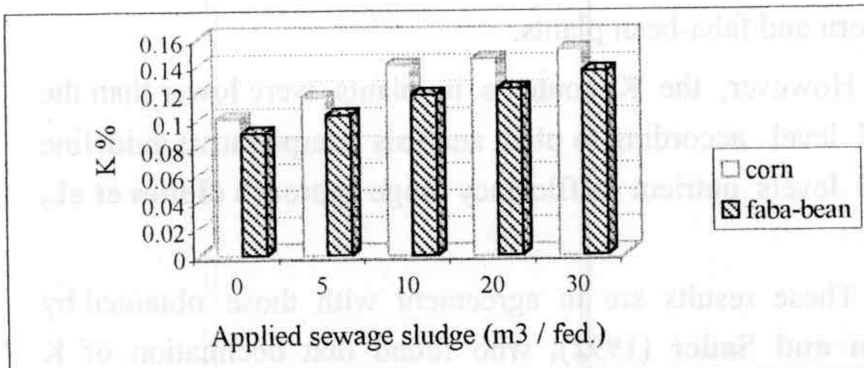

Fig. (21): Total K% in ear leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

reported that the increase of N and P contents in shoots and roots as a result of sewage sludge additions may be due to the increase of their availability in soil. The higher rates of sewage sludge (30 m^3 fed^{-1}) decreased the N and P content of the corn and faba-bean leaves. This may be due to the higher content of heavy metals especially Cd, Pb and Cu. Similar results were reported by **El-Keiy (1983)** and **Rabie et al. (1996).**

The lowest values of P in corn and faba-bean plants were observed in untreated with sewage sludge (control treatment). These results are in agreement with those obtained by **El-Keiy (1983),** who stated that the beneficial effects of sewage sludge application on plant growth were most often related to the control of N and P in plants. However, phosphorus concentration in plant leaves was around the normal level (0.22 % P), according to **Rashed and Din (1993).**

Data in Fig. (21) show that the concentration of K ranged from 0.1 to 0.15 % in corn leaves and from 0.09 to 0.135 % in the leaves of faba-bean plants. Increasing the rate of sewage sludge application to soil, increased K content in the leaves of both corn and faba-bean plants.

However, the K contents in plants were lower than the critical level according to plant analysis interpretative guideline critical levels nutrient sufficiency range approach **(Jones et al., 1991).**

These results are in agreement with those obtained by **Karlen and Sader (1992),** who found that declination of K content in plants caused by re-translocation of K into the roots and leaching from leaves. They also found that re-translocation of K in plants toward maturity is about 20 % lower than K content at harvest compared with the peak of the season.

As for K contraction in corn plants, it was higher than in faba-bean plants. These stimulatory effects may be due to plant species and seasonal variation in the soil **(Nye, 1981; Schaller, 1987** and **Youssef and Chino, 1989).**

4.6.3. Nutritive and non-nutritive heavy metal contents in plant:

4.6.3.1. Nutritive metals (Fe, Mn, Zn, Cu):

***Iron (Fe).**

Fe concentration in ear leaves of corn and faba-bean plants are illustrated in Table (10) and Fig. (22). The results clearly indicated an accumulation of Fe with sewage sludge application compared to control treatment. The Fe accumulation in plant tissue was widely variable according to the plant species and organism. Iron contents in ear leaves of corn were 427, 531, 1000, 1066 and 1433 mg kg^{-1}, and they were 269, 292, 321, 423 and 429 mg kg^{-1} in leaves of faba-bean plants grown in soils treated with sewage sludge at rates of 0, 5, 10, 20 and 30 m^3 fed^{-1}, respectively.

The results reveal that Fe contents in plant were significant increased with sewage sludge application (Table 10). Concentration of Fe in plants were not only ample, but also might reach above the sufficiency range. The same results were achieved by **Jones (1972)** who reported that the sufficiency values of Fe seems to be ranged from 50 to 250 mg kg^{-1}. On the

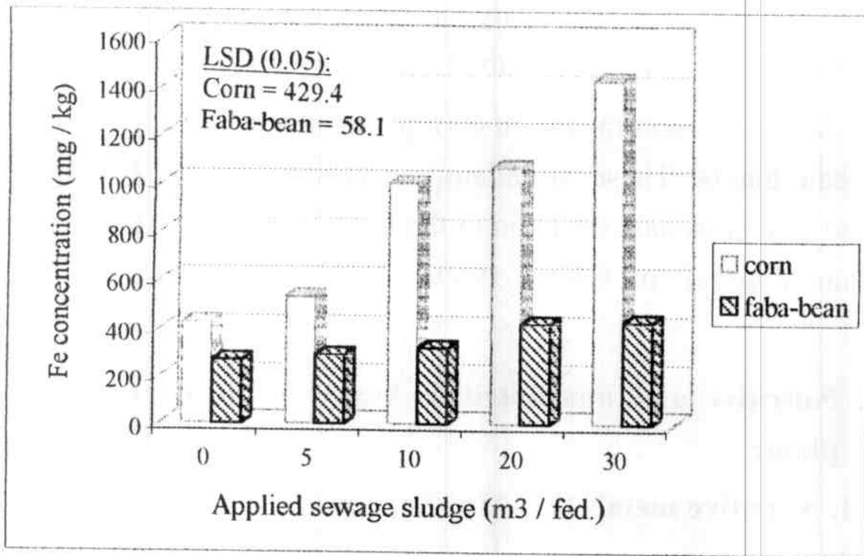

Fig. (22): Fe content in leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

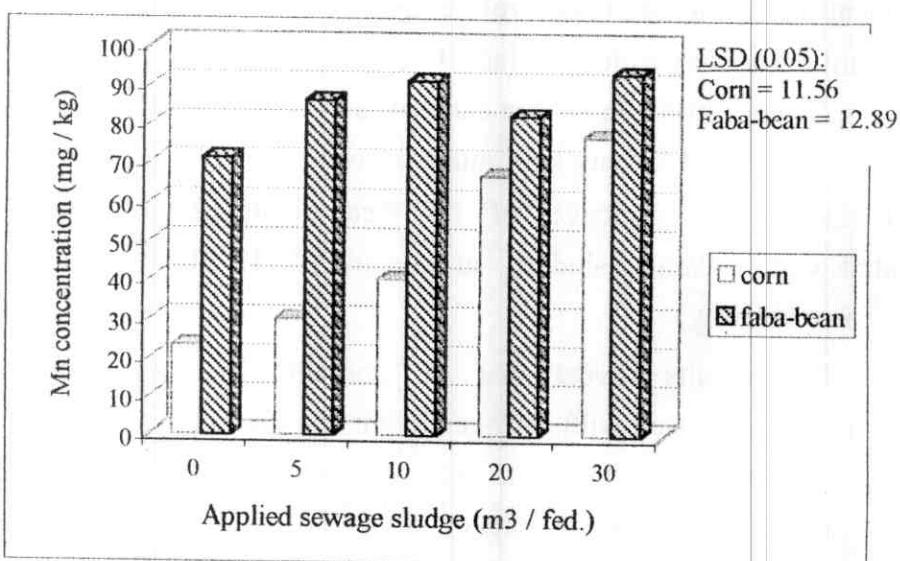

Fig. (23): Mn content in leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

other hand, data also show that there were high accumulation of Fe in corn leaves. These results are in agreement with those obtained by **El-Sebaay (1995),** who showed that the concentration of Fe in corn ear leaves collected from soils irrigated by mixed water was ranged from 920 to 1250 mg kg^{-1}.

*Manganese (Mn).

Data presented in Table (10) and Fig. (23) show that Mn were significant increased with sewage sludge application. These increases in leaves of corn plant were 23.3, 30.0, 40.0, 66.6 and 76.6 mg kg^{-1} and 71.0, 86.3, 91.0, 82.0 and 93.0 mg kg^{-1} in the leaves of faba-bean plants grown in soil mixed with sewage sludge at rates of 0, 5, 10, 20 and 30 m^3 fed^{-1}, respectively. These results are in agreement with those obtained by **Khalil (1990),** who mentioned that Mn contents in roots, shoots and seeds in the control plants of faba-bean were 32.5, 2.25 and 2.0 mg kg^{-1}, respectively. In soils treated with sewage sludge, Mn contents in the plants were 42.5, 35.0 and 2.5 mg kg^{-1}, respectively.

Data show that Mn contents in plants were not excessive or toxic to plants. **Jones (1972)** mentioned that ample concentration of Mn in plant tissues reach to 500 mg kg^{-1} but did not reach to the toxic level.

* Zinc (Zn).

Data presented in Table (10) and Fig. (24) show that Zn contents were significantly increased with sewage sludge application. These increases were 63.3, 76.6, 93.3, 110 and 123.0

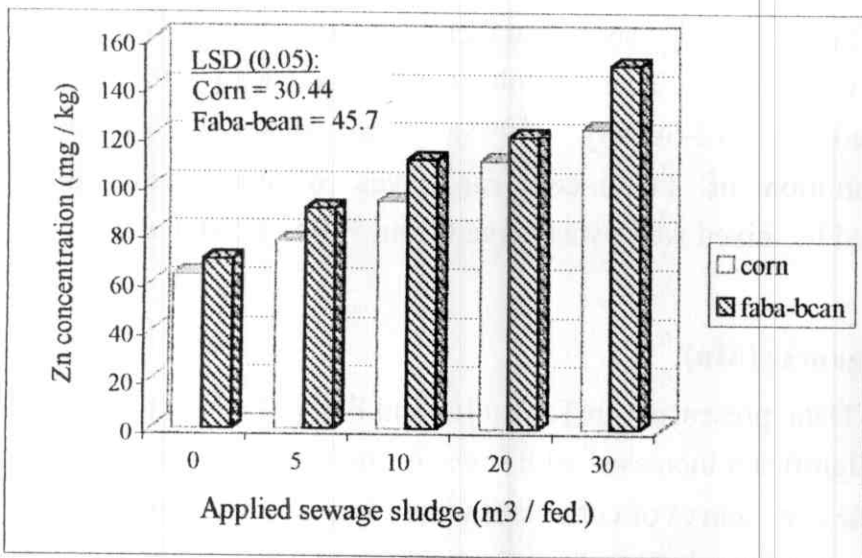

Fig. (24): Zn content in leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

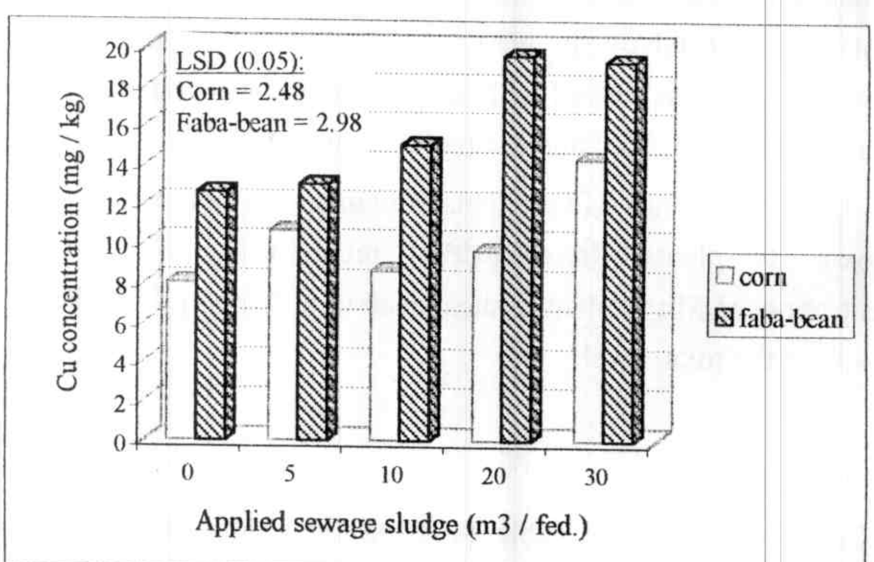

Fig. (25): Cu content in leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

mg kg^{-1} in the leaves of corn plants and 69.3, 90.3, 110.6, 119.6 and 149.3 mg kg^{-1} in the leaves of faba-bean plants grown in soil treated with sewage sludge at rates of 0, 5, 10, 20 and 30 m^3 fed^{-1}, respectively. However, Zn contents in corn and faba-bean plants are less than the optimum range according to **Jones (1972),** who mentioned that the ample concentration of Zn in plant tissues was 400 mg kg^{-1}.

Data in the same figure also, indicate that total Zn in corn and faba-bean plants increased with increasing sewage sludge rates added to soil. These results are in agreement with those obtained by **Khalil (1990),** who reported that zinc contents in roots, shoots and seeds of the control treatment of faba-bean plants were 21.4, 31.3 and 28.0 mg kg^{-1}, respectively. Whereas, they were 35, 80 and 65 mg kg^{-1}, respectively, in sewage sludge treatments.

*** Copper (Cu).**

Data presented in Fig. (25) show that Cu contents were 8.0, 10.6, 8.6, 9.6 and 14.3 mg kg^{-1} in the leaves of corn plants, and 12.6, 13.0, 15.0, 19.6 and 19.3 mg kg^{-1} in the leaves of faba-bean plants grown in soils treated with sewage sludge at the rates 0, 5, 10, 20 and 30 m^3 fed^{-1}, respectively. However, such contents of Cu are less than the optimum level (20 mg kg^{-1}), as reported by **Jones (1972).**

Also, the addition rates of sewage sludge significantly increased Cu content in the leaves of corn and faba-bean plants. These results are in agreement with those obtained by **Khalil (1990),** who reported that Cu content in roots, shoots and seeds of faba-bean plants grown in untreated and treated soil with sewage sludge were ranged from 8.3 to 10.8, 6.5 to 8.5 and 3.0 to 4.3 mg kg^{-1}, respectively.

4.6.3.2. Non-nutritive heavy metals (Pb and Cd):

*** Lead (Pb).**

Data illustrated by Fig. (26) show that the average contents of Pb ranged from 4.1 to 13.4 and from 2.63 to 14.83 mg kg^{-1} in the leaves of corn and faba-bean plants, respectively. Data show that Pb contents were higher than the normal level (1 mg kg^{-1} according to **Mitchell et al., 1978).** However, **Chapman (1968)** showed high excess value of Pb in the leaves of plants, which exceeded 13.5 mg kg^{-1}.

Data indicate that Pb content in corn and faba-bean plants were significantly increased with the addition rates of sewage sludge to the soil. These results are in agreement with those obtained by **Khalil (1990),** who reported that Pb contents in roots, shoots and seeds of the control treatment of faba-bean plants, and in soils treated with sewage sludge, they were ranged from 12.5 to 27.5, 5.3 to 8.75 and 1.75 to 2.5 mg kg^{-1}, respectively.

*** Cadmium (Cd):**

Data in Table (10) and Fig. (27) show that Cd contents in the leaves of corn and faba-bean plants ranged from 1.0 to 2.5 and from 1.0 to 2.0 mg kg^{-1}, respectively. Cd content in corn and faba-bean plants were significantly increased with sewage sludge

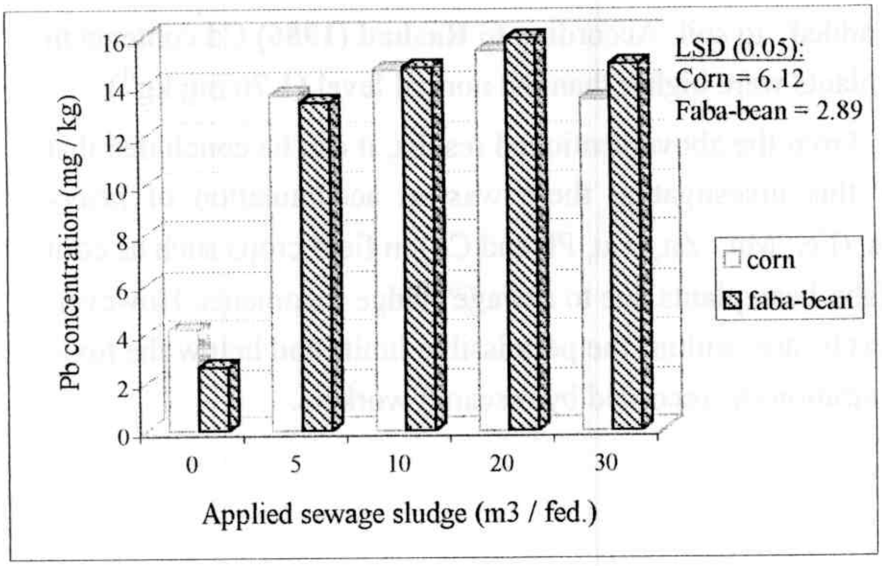

Fig. (26): Pb content in leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

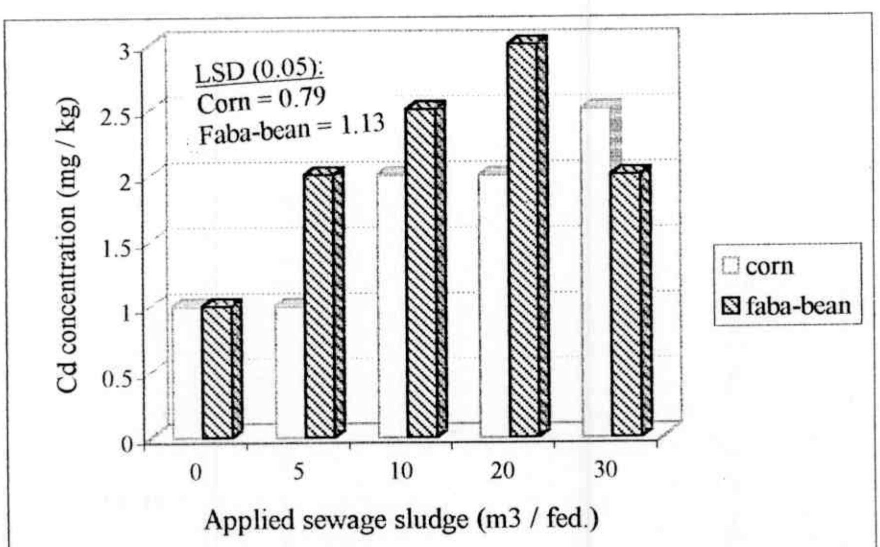

Fig. (27): Cd content in leaves of corn and faba-bean plants grown in soil treated with sewage sludge.

rates added to soil. According to **Rashad (1986)** Cd contents in these plants were higher than the normal level (1.76 mg kg^{-1}).

From the abovementioned results, it can be concluded that under this investigation there was an accumulation of heavy metals (Fe, Mn, Zn, Cu, Pb and Cd) in field crops such as corn and faba-bean plants due to sewage sludge treatments. However, the levels are within the permissible limits and below the toxic concentrations as recorded by research workers.