J.King Saud Univ., Vol. 15,*Agric. Sci*. (2), pp. 153-165, Riyadh (1423/2003)

Soil Science

Microbiological Studies on Some Organic Materials Used as Soil Conditioners

Abdullah M. Al-Falih* and Ali A. Al-Jaloud**
**Department of Science (Biology), Teachers College in Riyadh, P.O. Box 4341, Riyadh 11491, Saudi Arabia*
***Natural Resources and Environmental Research Institute, King Abdulaziz City for Science and Technology, P.O. Box 6086, Riyadh 11442, Saudi Arabia*

(Received 20/7/1422; accepted for publication 21/10/1422)

Abstract. Sewage sludge, dairy manure, compost and poultry manure were added to sandy soil at a rate of 0, 25, 50 and 75 Mg ha^{-1}. The effect of these organic materials on microbial population and enzymes activity was investigated. The addition of organic materials led to marked increase in soil salinity, microbial numbers and soil enzyme activities. All of these organic materials, with exception of compost, are rich in plant nutrients and heavy metals. Activities of the enzymes invertase, amylase, arylsulphatase, urease, dehydrogenase and phosphatase were also stimulated by the addition of organic materials. The optimum activity of soil enzymes reached at the rate of 50 Mg ha^{-1} of organic materials.

Keywords: Organic materials, soil conditioners, bacteria, fungi, actinomycetes, enzymes.

Introduction

Majority of soils in arid regions of the world are sandy, having low water holding capacity, low organic matter, salinity ranging from low to high in some areas and high evaporative conditions. As such, the germination and establishment of new plants are extremely difficult. It is therefore, important to provide the seeds and the new plants with a suitable environment at the initial stages for successful plantation to change the macro and micro-environment of these soils.

Most of the soils in Saudi Arabia are slightly alkaline and sandy in texture with low percentages of organic matter [1]. The desert soils of Saudi Arabia, are very poor in organic matter and have low plant nutrients, can be reclaimed by the application of chemical fertilizers which is very costly in large scale. Supplementation of different types of organic materials like animal manure and sewage sludge can be used as alternative for desert soils reclamation. Under such conditions, soil reclamation and desert greenification are very difficult tasks.

The application of sewage sludge to agricultural land adjacent to sewage works is a common practice in most parts of the world. In Saudi Arabia sewage sludge has become widely used on farms impute. The importance of sewage sludge as sources of N, P and K was assessed by different workers and attention was drawn to the possible dangers from accompanying heavy metals present [2,3]. The agricultural benefits of sewage sludge are well known, but increased levels of sludge in the soil will result in an increase in heavy metals [4,5].

Development of suitable mixtures of soil and organic materials is highly important for the expansion of greenery in arid and semi-arid countries of the world.

This study was formulated to develop different mixtures of sandy soils and locally available organic materials for promoting soil production in Saudi Arabia. The first part of this study aimed to investigate the effects of sewage sludge, dairy manure, poultry manure and compost on the enzyme activities and population of soil microorganisms. Enzyme activity was studied because it is likely to respond to the expected increased activity of the heterotrophic microbial population following organic materials amendment.

Materials and Methods

Soil samples and addition of organic materials

The experiment is being carried out in field at Al-Muzahmyia Research Station of King Abdulaziz City for Science and Technology, Riyadh, Saudi Arabia. The soil of the Research Station is mostly sandy in texture (Table 1) and calcareous with low seasonal rainfall and high evaporative conditions. The organic materials used were sewage sludge, dairy manure, poultry manure and compost. Application rates of these organic materials were 0, 25, 50 and 75 Mg ha^{-1}. A total number of 52 plots (each 2m x 2m size) were prepared and a complete randomized block design was followed for the experimental layout. After one month of organic materials application, the microbial numbers and enzyme activities were determined as below.

Table 1. Soil physical characteristics

Mechanical fraction %			Texture class	Organic matter %	pH	T.S.S mg/kg	E.C. mS/cm
Sand	Silt	Clay					
92.6	1.2	6.2	Sand	0.05	7.4	952	1.36

Chemical analysis of organic materials

For mineral analysis, one gram of the homogenious sieved samples were placed in a 100 ml beaker and digested with 20 ml conc. H_2SO_4 at 100^oC for 15 min (five replicates for each type of organic materials). After digestion, the digest was made up to 50 ml by deionised water. Nitrogen, phosphorus, potassium, calcium, magnesium, sodium, iron, copper, zinc, manganese, cadmium and nickle were analyzed using Atomic Absorption Spectrophotometer (Pye Unicam SP^9 equipped with SP^9 computer). The organic matter percentage was determined colorimetrically using the method described by Walinga *et al.* [6], by estimating the organic carbon and then convert it to organic matter using a factor of 1.724.

Numeration of soil microorganisms

For the quantitative estimation of fungi, actinomycetes and bacteria the dilution plate method of Waksman as described by Johnson and Curl [7] was used. Soil (1 g) was shaken in sterile Ringer's solution (10 ml) for 15 min. Samples of the resulting suspension were then serially diluted in Ringer's solution. The final dilution was then spread on the surface of the medium. Incubation periods were 3 days at 30^{o}C for total bacteria and 5-7 days at 30^{o}C for total fungi and actinomycetes.

Determination of soil enzymes

Arylsulphatase, phosphatase, invertase and dehydrogenase activities were determined respectively using the methods described by Tabatabai and Bremner [8]; Tabatabai and Bremner [9]; Frankenberger and Johanson [10] and Benefield *et al*., [11]. Amylase and urease activities were determined as described by Duddridge and Wainwright [12], except that 5 g of soil was used instead of sediment. All enzyme activities were measured in triplicate.

Statistical analysis

Standard statistical procedures were applied and a Minitab-for-Windows program was used for data analysis. The computer package analysis of variance (ANOVA Oneway Unstacked) was used in the data analysis, while theoretical procedures of statistical analysis were done according to Snedecor and Cochran [13].

Results

Organic materials were analyzed to determine the level of various plant nutrients (Table 2). The organic materials differ in their mineral composition. In the present study, the concentration of plant nutrients on the organic materials varied from one to another. Nitrogen concentration in the different types of organic materials tested ranged from 0.73 to 1.88 %; phosphorus from 0.04 to 1.09%; potassium from 0.13 to 2.07 %; calcium from 1.87 to 8.18 %; magnesium from 0.55 to 2.29%; sodium from1276 to 4427 mg kg^{-1}; iron from 1261 to 9351 mg kg^{-1}; copper from 18 to 168 mg kg^{-1}; zinc from 50 to 1088 mg kg^{-1}; manganese from 84 to 481 mg kg^{-1}; cadmium from 0.39 to 2.32 mg kg^{-1}; nickle from 11 to 74 mg kg^{-1} and organic matter from 23 to 63 %. The analysis indicates that all of the organic materials are rich in plant nutrient elements except compost which contains less of N P K as compared to other organic materials.

Table 2. Chemical composition of organic materials

	Organic materials			
Component	**Sewage sludge**	**Compost**	**Poultry manure**	**Dairy manure**
N (%)	1.71 ± 0.3*	0.73 ± 0.1	1.88 ± 0.7*	0.74 ± 0.5
P (%)	0.39 ± 0.2	0.04 ± 0.0	1.09 ± 0.4**	0.19 ± 0.1
K (%)	0.39 ± 0.1	0.13 ± 0.1	2.07 ± 0.6**	1.39 ± 0.3*
Ca (%)	6.43 ± 1.2*	1.87 ± 0.7	8.18 ± 0.0*	4.25 ± 1.0
Mg (%)	0.55 ± 0.1	0.16 ± 0.0	2.29 ± 0.3	0.59 ± 0.2
Na (mg kg^{-1})	2292 ± 18	1276 ± 134	1987 ± 86	4427 ± 59**
Fe (mg kg^{-1})	9351 ± 234**	1261 ± 79	2844 ± 256	4080 ± 46*
Cu (mg kg^{-1})	168 ± 32**	18 ± 0.9	59 ± 1.4	31 ± 0.8
Zn (mg kg^{-1})	1088 ± 56**	50 ± 1.5	475 ± 28	108 ± 4.1
Mn (mg kg^{-1})	150 ± 7.0	84 ± 0.8	481 ± 31**	250 ± 12*
Cd (mg kg^{-1})	2.32 ± 0.3	0.39 ± 0.0	0.73 ± 0.1	0.65 ± 0.2
Ni (mg kg^{-1})	74 ± 2.8**	11 ± 0.6	17 ± 0.5	31 ± 1.4
Organic matter (%)	40 ± 1.9	63 ± 7.0	39 ± 0.8	23 ± 0.3
C / N ratio	13.6 ± 0.4	50.1 ± 2.3**	12.0 ± 0.0	18.0 ± 0.5

All values are means of triplicates ± S.D. *: Significant, **: Highly significant at 0.01

The application of organic materials increased soil salinity concentration (total soluble salts) from approximately 952 to 5691 mg kg^{-1}; increase in salinity was associated with corresponding increase in application rate (Fig. 1). Addition of dairy manure exhibited the highest concentration of total soluble salts in soil samples, while the compost showed almost constant level of total soluble salts through the different

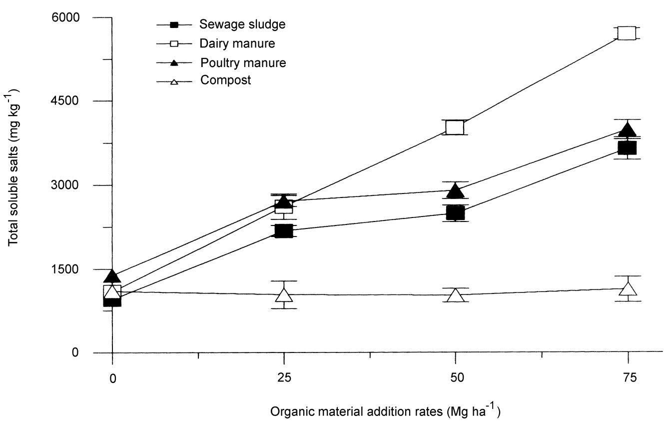

Fig. 1. Concentration of total soluble salts in soil amended with different types of organic materials.

application rates.

Numbers of bacteria, fungi and actinomycetes in soil amended with different types of organic materials are shown in Figs. 2a to 2c. The addition of organic materials led to a marked increase in numbers of soil microorganisms. The highest total count of bacteria, fungi and actinomycetes was recorded in soil supplemented with sewage sludge followed by poultry manure. The bacterial total count increased from 1.3 x 10^2 to 4.5 x 10^8 per gram dry soil following the addition of organic materials (Fig. 2a). The lowest number of bacteria was observed in soil receiving dairy manure (0.7 x 10^4 per gram dry soil). On the other hand, fungal numbers were increased from 4.9 x 10 in control soil to 6.1 x 10^6 per gram dry soil in sewage sludge treatments (Fig. 2b). Actinomycetes total count ranged from 8.3 x 10 in soil amended with compost to 2.7 x 10^4 per gram dry soil amended with sewage sludge (Fig. 2c).

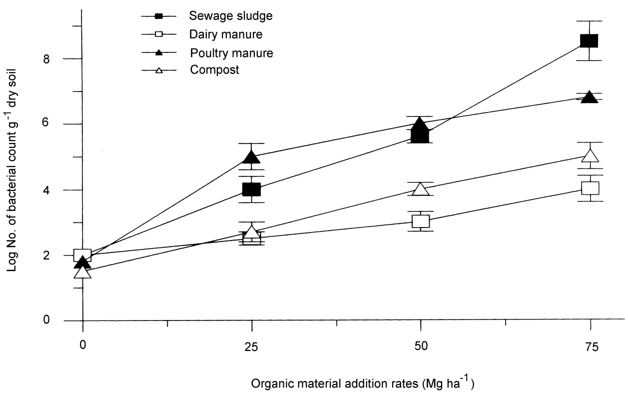

Fig. 2a. Changes in total counts of soil bacteria following the amendment of different types of organic materials.

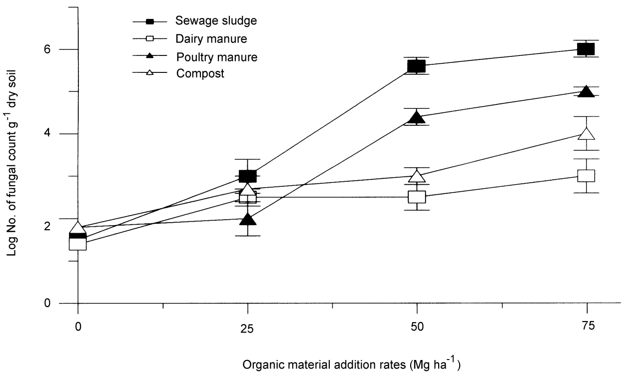

Fig. 2b. Changes in total counts of soil fungi following the amendment of different types of organic materials.

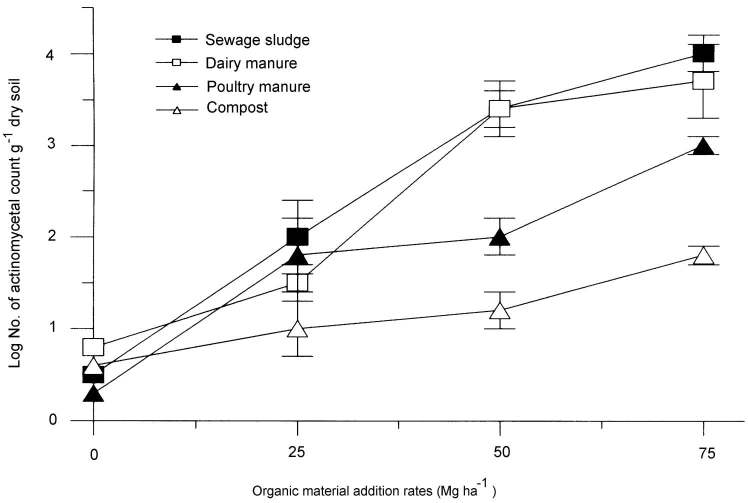

Fig. 2c. Changes in total counts of soil actinomycetes following the amendment of different types of organic materials.

Figure 3 illustrates the activity of soil enzymes following the addition of organic materials as a soil improvers. Application of sewage sludge, dairy manure, poultry manure and compost increased the activity of soil enzymes. The maximum activity level of invertase, amylase, arylsulphatase, urease, dehydrogenase and phosphatase was recorded at 50 Mg ha^{-1} of organic materials and then fell down at the rate of 75 Mg ha^{-1}. The highest activity of invertase (9.1 mg glucose hydrolysed g^{-1} dry soil $24h^{-1}$), amylase (8.5 mg starch hydrolysed g^{-1} dry soil $6h^{-1}$), arylsulphatase (90 µg SO_4 g^{-1} dry soil $1h^{-1}$) and urease (1200 µg urea-N hydrolysed g^{-1} dry soil $8h^{-1}$) were shown following sewage sludge amendment at the rate of 50 Mg ha^{-1} (Figs. 3a, 3b, 3c and 3d). While addition of dairy manure exhibited the highest activity of dehydrogenase enzyme that was 570 µg formazan g^{-1} dry soil $24h^{-1}$ at the rate of 50 Mg ha^{-1} (Fig. 3e). In the case of phosphatase enzyme the poultry manure amendment gave the highest activity of this soil enzyme with 489 µg P_2O_5 g^{-1} dry soil $1h^{-1}$ (Fig. 3f).

Discussion

Application of sewage sludge followed by poultry manure exhibited the highest level of bacterial, fungal, actinomycetal numbers and enzyme activities. Although the compost has the highest percentage of organic matter, it showed the lowest effect on microbial numbers and enzyme activities which may be attributed to the slow decomposition of compost to release organic matter by soil microorganisms. The maximum activities of studied soil enzymes were observed in soil supplemented with sewage sludge and poultry manure because they had the highest level of nitrogen,

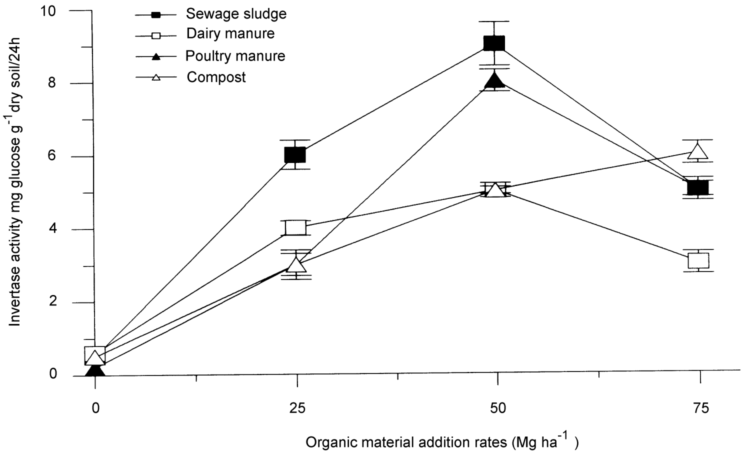

Fig. 3a. Changes in soil invertase activity following the amendment of different types of organic materials.

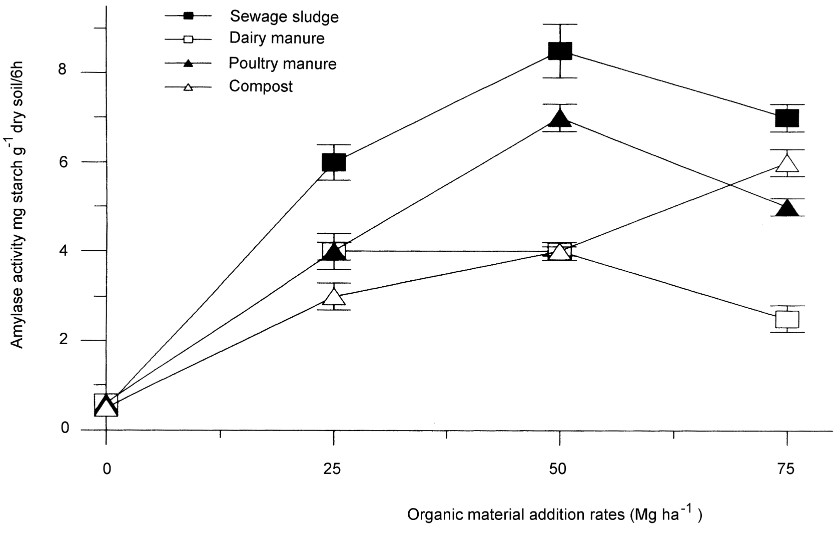

Fig. 3b. Changes in soil amylase activity following the amendment of different types of organic materials.

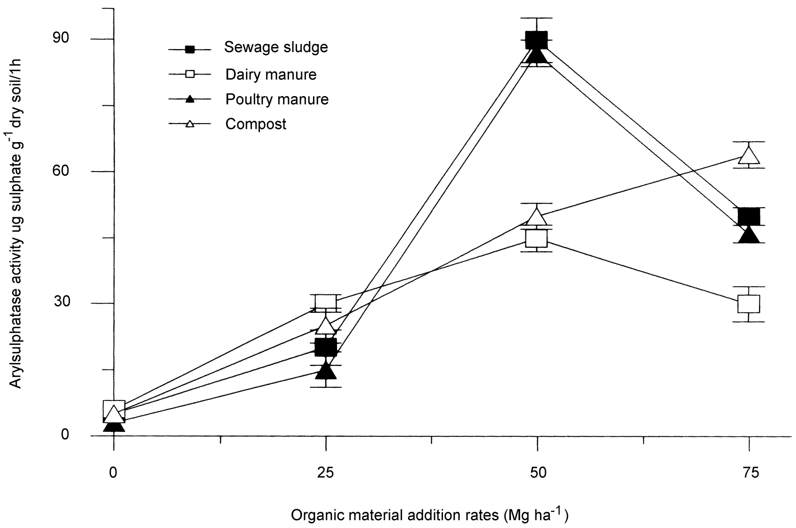

Fig. 3c. Changes in soil arylsulphatase activity following the amendment of different types of organic materials.

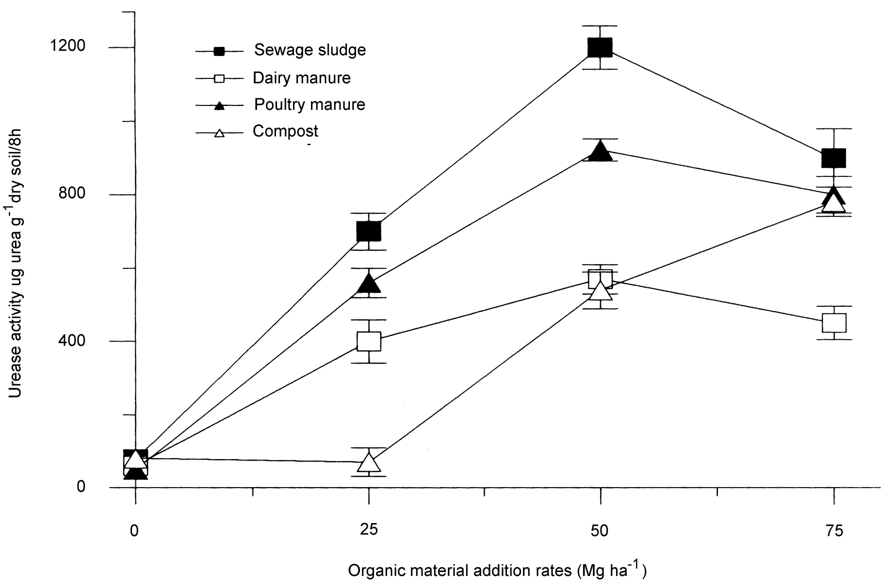

Fig. 3d. Changes in soil urease activity following the amendment of different types of organic materials.

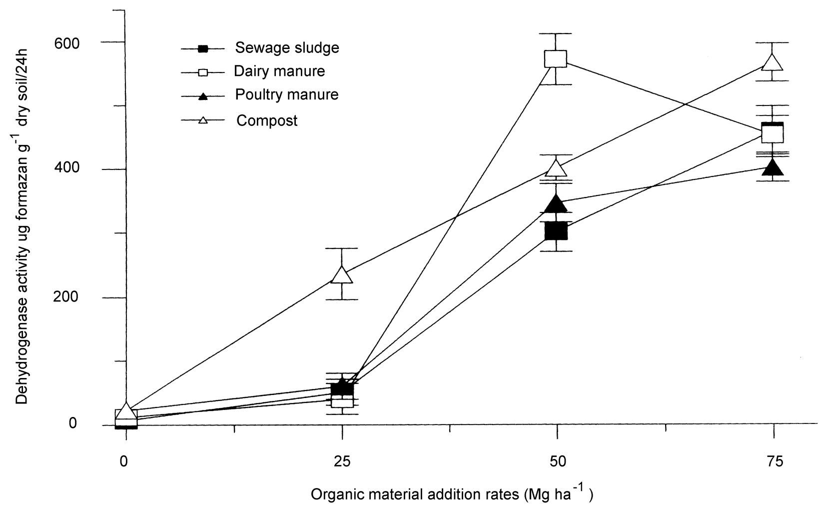

Fig. 3e. Changes in soil dehydrogenase activity following the amendment of different types of organic materials.

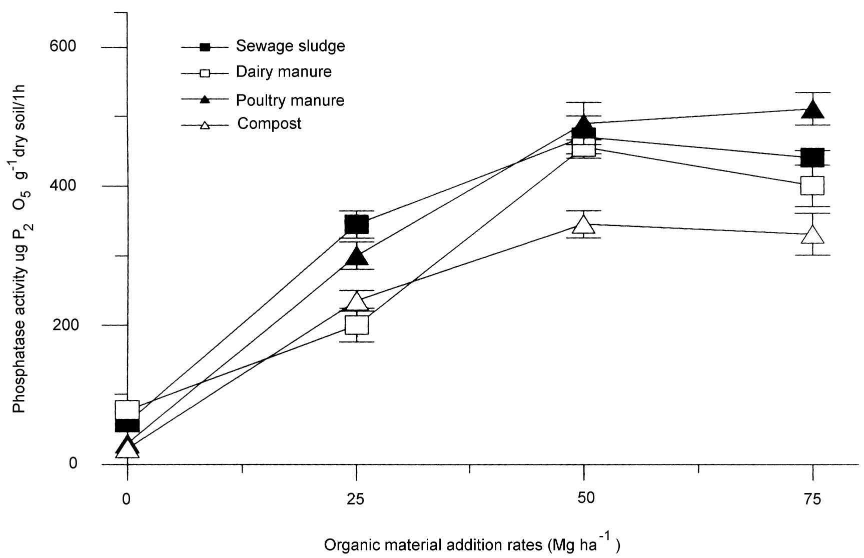

Fig. 3f. Changes in soil phosphatase activity following the amendment of different types of organic materials.

phosphorus and potassium. The poultry manure recorded the highest activity of phosphatase enzyme because it has organic-phosphorus compounds which were easily to decompose by soil microorganisms.

Increased enzyme activities in soil amended with organic materials may reflect the stimulating microbial production by adding organic materials to the soil as a source of nutrition. Addition of different organic materials to the soil increased organic matter content and promoted microbial activity (enzymes producing microorganisms). Numerous studies have shown that enzyme activities in soils increases with increasing organic matter content [10, 12, 14-17]. Since organic materials addition leads to an increase in easily available carbon, thereby stimulating soil microbial activity, the marked increase in enzyme activities in the amended soil is therefore not surprising. Zantua and Bremner [18], among others, in studies of the effects of different amount of glucose, starch, cellulose, animal manures, plant materials and sewage sludges on urease activity have shown a similar increase in urease activity following glucose addition, with a resultant increase in soil microbial activity.

Overall, the results show that the activity of invertase, amylase, arylsulphatase, urease, dehydrogenase and phosphatase enzymes decreased at the rate of 75 Mg ha^{-1} of organic materials application. This is probably because sewage sludge, dairy manure and poultry manure are rich in heavy metal elements. But since the heavy metal concentrations in the compost is moderate, so the enzyme activity increased with an increase in the amount of compost application. Hashem [2] reported that the sewage sludge generally contains relatively large amounts of heavy metals. The application of sewage sludge to agricultural lands will result in high content of heavy metals which undoubtly will affect the soil properties and plant growth. But as sewage sludge disposal has become a major public health and ecological problem, therefore, it can be applied in low quantity to reduce its adverse effects.

Since the compost had the highest percentage of organic matter, which is the main source of dehydrogenase producing microorganisms, so addition of the compost showed the highest activity of dehydrogenase enzyme.

Bacterial flora was highly significant correlated with total soluble salts. But, there was no correlation between heavy metal concentrations in organic materials and bacterial counts. In fact, bacterial numbers are more closely correlated with total soluble salts, suggesting that this may be a more important limiting factor than the heavy metals. This result is consistent with the findings of previous studies on Saudi Arabian and other soils [1, 19-21]. On the other hand, fungal numbers were not correlated with total soluble salts but negatively correlated with heavy metal contents. Therefore, heavy metals may be the more important limiting factor of mycoflora growth in soil than total soluble salts. A similar relationship between salt content and number of fungi in the soil were reported earlier in Saudi Arabian soils by Hashem [1, 22].

It is usually under soil conditions of either high pH, high water stress, high salinity, or high temperature, that the actinomycetes really predominate [21]. On the whole the actinomycetes are resistant to salts, it can tolerate a high salt stress. The results of this study showed that both of sewage sludge and dairy manure exhibited the highest numbers of actinomycetes even though these organic materials had the maximum level of total soluble salts.

In conclusion, addition of sewage sludge, dairy manure, compost and poultry manure led to a marked increase in soil salinity, microbial numbers and soil enzyme activities. All of these different types of organic materials, with exception of compost, are rich in plant nutrients and heavy metals. Activity of the enzymes invertase, amylase, arylsulphatase, urease, dehydrogenase and phosphatase were all stimulated by the organic materials amendment. The optimum activity of soil enzymes reached at the rate of 50 Mg ha^{-1} of organic materials.

Finally, the use of such organic materials as fertilizers or soil conditioners is not without serious hazards particularly when used at high rates of application over a number of years.

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دراسات ميكروبيولوجية على بعض المواد العضوية المستخدمة كمحسنات للتربة

عبدالله مساعد الفالح و علي عبدالله الجلعود*

قسم العلوم (الاحياء)، كلية المعلمين بالرياض، ص.ب: ٤٣٤١ الرياض ١١٤٩١

**معهد بحوث الموارد الطبيعية والبيئة، مدينة الملك عبدالعزيز للعلوم والتقنية،*

ص.ب: ٢٨٣٢٢ الرياض ١١٤٣٧، المملكة العربية السعوديه.

(قدم للنشر في ٢٠/٦/ ١٤٢٢؛ وقبل للنشر في ٢١/١٠/١٤٢٢هـ)

ملخص البحث. تم إضافة مخلفات الصرف الصحي والسماد البقري والكمبوست وسماد الدواجن الى تربة رملية بمعدل 0, 25, 50, 75 Mg /ha. ودرس تأثير إضافة هذه المواد العضوية على الأعداد الكلية للميكروبات ونشاط الإنزيمات.

تشير الدراسة إلى أن إضافة هذه المواد العضوية أدى إلى زيادة معنوية في ملوحة التربة وأعداد الميكروبات ونشاط إنزيمات التربة. فيما عدا الكمبوست وجد أن هذه المواد العضوية غنية بالمعادن الغذائية اللازمة لنمو النبات والمعادن الثقيلة. إضافة المواد العضوية حفز نشاط كل من إنزيمات الإنفرتيز والأميليز والأريلسلفتيز واليورييز والديهيدروجينيز والفوسفتيز.

سجل أعلى معدل لنشاط الإنزيمات السابق ذكرها عند إضافة 50 Mg /ha من المواد العضوية.