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Effect of Soil Physico-Chemical Properties and Plant Species on Bacterial Diversity in Semi-Arid Parts in Central Sudan. Part III: AL-Gaeli Region, Khartoun North

Hatil Hashim EL-Kamali[1*], Hayat Ibrahim Hassan[1], Mustafa Siddig Mohamed EL-Kheir[2]

[1]Department of Botany, Faculty of Science and Technology, Omdurman Islamic University, Omdurman, Sudan
[2]Department of Biotechnology, Faculty of Science and Technology, Omdurman Islamic University, Omdurman, Sudan
Email: *hatilhashim@gmail.com

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Abstract

Bacterial diversity and total viable counts of bacteria of the different soil samples from three different localities in AL-Gaeli region, Khartoum North: Kunger, Gary and WadiAb-Gadad sub-regions were carried out. Soil physical and chemical characteristics (pH, EC, SP, soluble cations: Na, K, Ca, Mg and anion P, organic carbon, total nitrogen and soil texture) in each studied sub-regions were measured. Qualitative analysis of microorganisms isolated from the studied soil samples reveal a total of eight different species of bacteria, of which two are unidentified. The six species are classified under *Bacillus* genera. In study region soil samples, total bacterial counts ranged from 8.5×10^5 cfu·g^{-1} to 1×10^4. The quantitative data on microbial population recorded in the present study was analysed using two diversity indices. *Actinomyces* spp. and *Streptomyces* spp. were the most abundant microorganisms identified in the three sub-regions. There were obvious differences in correlation coefficients among the selected criteria that 65% from the total number of correlation coefficients were positively correlated between bacterial counts and soil physico-chemical properties. The development of molecular techniques of microbial identification, coupled with traditional methods is promising areas for continued research.

Subject Areas

Ecology

Keywords

Microbial Diversity, Physico-Chemical Properties, Soils, Semi-Arid Region, Khartoum North, Central Sudan

1. Introduction

Continuing our research works on the relationships between soil physico-chemical properties, plant species and soil microorganisms populations in semi-arid parts in Sudan [1] [2], we have study correlations between these parameters in AL-Gaeli region, Khartoum North, Central Sudan.

Soil is a complex habitat, inhabited by a large number of different organisms. Among these, bacteria and fungi are the most important since they are responsible for the vast bulk of decomposition, and also make up the largest part of the biomass in soil. Many of the essential transformations in the nitrogen, sulphur, phosphorus and other element cycles are mediated by microbes. Bacteria are the most abundant microorganism group in soil and can attain concentrations of more than 10^8 cells per gram of soil, or 10^{11} per gram organic material (cited by Pettersson, 2004) [3].

Soil organisms (biota) carry out a wide range of processes that are important for soil health and fertility in both natural and manged agricultural soils. The total number of organisms, the diversity of species and the activity of the soil biota will fluctuate as the soil environment changes. These changes may be caused by natural or imposed systems. The activity of soil organisms can be divided into four functions: 1) regulation of organic matter turnover and nutrient cycling, 2) biological degradation, 3) maintenance of soil structure, and 4) interaction with plants. The main factors contributing to the soil environment are: i) soil texture and structure; ii) nutrient status; iii) soil pH; iv) moisture and temperature; v) surface plants; vi) Inputs and vii) compaction. There are a number of environmental factors that affect the bacterial community. Some of these factors are called modulators, in contrast that resources that the microbial community needs for growth (e.g. carbon, nitrogen). The difference between modulators and resources is that organisms actively compete for resources, while they cannot compete for modulators. As one of the most important environmental factors, pH has a determining role in the type of organisms that predominate in different soils (cited by Pettersson, 2004) [3].

Soil microbial communities develop in response to constraints, and selection pressures in their environmental (physical, chemical and biological). The chemical and biological constraints have been studied extensively [4] [5] [6]. In contrast, ways in which the physical environment of soil exerts control over community structure and diversity are more poorly understood.

The objectives of this study were: 1) to obtain a better understanding of the correlations between microbial population and physico-chemical properties of different soil types in study area; 2) to study how plant species and soil type affects the microbial diversity and abundance; 3) to explain the differences among tested habitats.

2. Materials and Methods

Study site description and soil sampling:

Soils were collected from three different sub-regions (Kunger, Gary and Wa-

diAb-Gadad sub-regions in the Khartoum State, in arid/semi-arid parts in Central Sudan. The research work in this study had been carried out in arid/semi-arid regions of Central Sudan, around latitude 15˚50'N and longitude 32˚55'E. Soil samples were collected from 0 - 5 cm and 5 - 15 cm depths and kept in plastic bag. After collection, soil samples were brought to the laboratory and separated into two sub samples; one for bacteriological analysis that was kept in a refrigerator and the other one for the analysis of soil physico-chemical properties. Soil sampling was done in December, 2011.

Bacteriological analysis:

Nutrient agar medium was used for the enumeration of bacteria present in soil samples [7]. The pH was adjusted before addition of agar and sterilization. Serial dilution plate technique was used for the isolation of microorganism. One gram soilsample was diluted (1:100) with 100 ml distilled water in a sterile conical flask and shaken well. One ml of this suspension was transferred to 9 ml of sterile water for tenfold (1:10) dilution and by following serial dilution further diluted up to 10^5 times. Plating in duplicate plates was made for each diluted sample. One ml of each of the diluted sample was taken in a sterilized petri dish by pipette. Then, molten agar medium was poured and mixed thoroughly by rotating the petri dish, first in one direction and then in the opposite direction. After setting the medium, the plates were inverted and incubated at 37˚C for 48 h in an incubator then, the plates having well discrete colonies were selected for counting. The selected plates were placed on a colony counter (Digital colony counter, DC-8OSK1000086, Kayagaki, Japan) to count the number of colonies.

Tests:

Motility test was determined according to Cruickshank *et al*., 1975 [8]. Catalase test Oxidation-Fermentation test (O/F), Oxidase test, Sugar fermentation test, Voges-Proskauer test, Nitrate reduction test, Indole production test, Urease test, Citrate utilization were determined according to Barrow and Feltham 1993 [9]. Casein hydrolysis was determined by method described by Williams and Cross, 1971 [10]. Starch hydrolysis was performed according to Collins *et al*., 1995 [11]. Total a viable count of bacteria was determined [12].

Isolation of Streptomyces:

Isolation of *Streptomyces* was performed by the soil dilution plate technique [13]. In this technique; 1 g of each soil sample was taken in 9 ml of sterilized distilled water in pre-sterilized test tube. Serial aqueous dilutions (10^{-2} - 10^{-7}) were prepared by transferring 1 ml of the soil suspension into 9 ml of sterilized distilled water in sterilized test tubes. Different aqueous dilutions (10^{-4} thro-10^{-6}) of the soil suspensions were applied separately into sterilized Petri-dishes and 20 ml of Starch-Casein Agar salt medium, $SCKNO_3$, was added, mixed thoroughly and the plates were incubated at 28˚C for 7 - 14 days. $SCKNO_3$ medium was prepared by dissolving 10 g soluble starch, 2 g dipotassium hydrogen ortho-phosphate, 2 g potassium nitrate, 2 g sodium chloride, 4 g casein, 0.05 g hydrated magnesium sulphate, 0.1 g calcium carbonate; 0.01 g hydrated ferric sulphate, 15 g agar in one liter of distilled water. The medium was sterilized by au-

toclaving at 121˚C for 15 minutes. Colonies characteristic of Streptomycetaceae (rough, chalky, powdery and with earth odour) that appeared on the incubated plates were selected, repeatedly sub-cultured for purification and stored at 4˚C onto slants of $SCKNO_3$ medium until further examinations.

Analysis of soil physico-chemical properties:

The pH of the soil was measured in a soil water suspension (1:2, soil:water). The electrical conductivity (EC) analysis was measured in the saturated extract. Na+ and K+ were determined photometrically. The exchangeable cations (Ca^{++} and Mg^{++}) were determined by Atomic Absorption Spectrophotometer (AAS, Perkin-Elmer, 047-1705. Saturated percentage (SP) were also determined [14]. Organic carbon content of the soil was determined by Wakely and Black method (Cited by Moghimi *et al*., [15]). Total nitrogen (%) was determined by Kjeldahl method following extraction from 2 g soil with conc. H_2SO_4. The particle size analysis was carried out by the Pipette method (Cited by Moghimi *et al*., 2013 [15]).

Once the percentage of sand, silt, and clay is measured, the soil may be assigned a textural class using the table of textural soil types (cited by Subrahmanyam and Sambamurty) [16].

Bacterial diversity measures:

1/Shannon-Weiner Biodiversity Index:

Species diversity

$$(H) = -(P_i)(\log_2 P_i)$$

where: P = The proportion of all individuals in the sample which belongs the species *i*.

2/Simpson Index:

$$D = 1 - \sum_{i-1} S(Pi)^2$$

where: D is the index number; S = the total number of species; P = the proportion of all individuals in the sample which belongs to species *i*.

(Cited by Subrahmanyam and Sambamurty [16])

The soil characteristics in AL-Gaeli region:

1) Kunger sub-region:

The soil of this sub-region is predominantly clay loam. The pH of soil samples ranged from 7.49 to 7.34. The EC values varied from 2.75 - 0.86 mmohs/cm. The total nitrogen was in range 0.91 - 0.035. Organic carbon range between 0.36 and 0.64%. C:N ratio range between 6:1 and 13:1. The SP ranged from 50.7% - 28.4%. Sodium contents ranges between 0.906 and 2.958 Meq/L. As for K it varies between 0.142 and 0.379 Meq/L. Calcium contents was found to vary between 4 - 19 Meq/L. Magnesium contents was found to vary between 2 and 10 Meq/L. P contents ranged between 3.2888 and 3.3636 ppm.

2) Gary sub-region:

The soil of this sub-region is predominantly sandy clay loam. The pH of soil samples ranged from 7.24 to 7.78. The EC values varied from 0.267 - 0.53 mmohs/cm. The total nitrogen was in range 0.028 - 0.14. Organic carbon range

between 0.26% and 0.65%. C:N ratio range between 5:1 and 13:1. The SP ranged from 22.1% - 31.4%. Sodium contents ranges between 0.513 and 1.77 Meq/L. As for K it varies between 0.104 and 0.372 Meq/L. Calcium contents was found to vary between 1.5 - 3.50 Meq/L. Magnesium contents was found to vary between 0.25 and 1.5 Meq/L. P contents ranged between 0.0 and 1.587 ppm.

3) WadiAb Gadad sub-region:

The soil of this sub-region is predominantly sandy clay loam. The pH of soil samples ranged from 7.51 to 7.63. The EC values varied from 0.242 - 0.38 mmohs/cm. The total nitrogen was in range 0.021 - 0.042. Organic carbon range between 0.19% and 0.40%. C:N ratio range between 7:1 and 17:1. The SP ranged from 22.5% - 26.3%. Sodium contents ranges between 0.936 and 1.721 Meq/L. As for K it varies between 0.085 and 0.124 Meq/L. Calcium contents was found to vary between 1.5 - 4.5 Meq/L. Magnesium contents was found to vary between 0.5 and 2.0 Meq/L. P contents ranged between 0.0 and 1.169 ppm.

3. Results and Discussion

The results concerning soil physical and chemical characteristics (pH, EC, SP, soluble cations: Na, K, Ca, Mg and anion P, organic carbon, total nitrogen and soil texture in three different studied sub-regions are presented in Tables 1-3.

Ten organisms were isolated from collected soil samples; *Actinomyces* spp., *Streptomyces* spp., *Bacillus lentus*, *Bacillus badius*, *Bacillus pantothenticus*, *Bacillus circulans*, *Bacillus subtilis*, *Bacillus cereus*, *Micrococcus varians and*

Table 1. Some soil physico-chemical properties of different samples from AL-Gaeli region-Kunger sub-region.

Sample No.	Soil Depth	Bacterial count (CFU/g)	pH	EC mmohs/cm	N %	O.C %	SP %	Na Meq/L	K Meq/L	P ppm	Ca Meq/L	Mg	Clay %	Silt %	Sand %	Textural Soil Types
KUN1	0 - 5	8.5×10^5	7.35	2.75	0.077	0.46	28.4	2.958	0.577	2.455	28	11.5	33	24	43	Clay loam
KUN2	5 - 15	3×10^4	7.35	1.82	0.042	0.4	50.7	2.898	0.385	0	17.5	3	33	22	45	Clay loam
KUN3	0 - 5	8.5×10^5	7.41	0.86	0.049	0.63	28.4	0.906	0.295	2.125	6	2.5	29	16	56	Sandy clay loam
KUN4	5 - 15	1.2×10^5	7.49	0.97	0.091	0.64	48.2	1.932	0.203	0	5.5	2.5	33	44	23	Clay loam
KUN5	0 - 5	1.1×10^4	7.34	1.062	0.035	0.36	57.1	2.747	0.202	0	7	3.5	31	48	21	Clay loam
KUN6	5 - 15	1.5×10^5	7.43	1.56	0.049	0.40	48.2	2.808	0.256	0	11.5	3.5	21	36	43	Loam

Table 2. Some soil physico-chemical properties of different samples from AL-Gaeli region-Gary sub-region.

Sample No.	Soil Depth	Bacterial count (CFU/g)	pH	EC mmohs/cm	N %	O.C %	SP %	Na Meq/L	K Meq/L	P ppm	Ca Meq/L	Mg Meq/L	Clay %	Silt %	Sand %	Textural Soil Types
GAR1	0 - 5	1.7×10^2	7.45	0.32	0.14	0.65	25.5	0.513	0.181	1.587	3	1	20	2	78	Sandy loam
GAR2	5 - 15	7.5×10^4	7.61	0.244	0.063	0.63	22.1	1.147	0.106	0.896	1.5	1	20	2	78	Sandy loam
GAR3	0 - 5	1.5×10^4	7.24	0.267	0.042	0.46	31.4	0.845	0.154	1.10	2.5	1	24	22	54	Sandy clay loam
GAR4	5 - 15	7.5×10^3	7.28	0.28	0.043	0.53	25.9	1.177	0.104	0	1.5	1	33	14	53	Sandy clay loam
GAR5	0 - 5	1.2×10^5	7.71	0.53	0.049	0.64	26.3	1.087	0.372	0	3.5	1.5	20	9	71	Sandy clay loam
GAR6	5 - 15	1.6×10^4	7.78	0.281	0.028	0.26	23.4	0.905	0.172	0	2	0.25	35	27	39	Clay loam

Table 3. Some soil physico-chemical properties of different samples from AL-Gaeli region-WadiAb-Gadad sub-region.

Sample No.	Soil Depth	Bacterial count (CFU/g)	pH	EC mmohs/cm	N %	O.C %	SP %	Na Meq/L	K Meq/L	P ppm	Ca Meq/L	Mg Meq/L	Clay %	Silt %	Sand %	Textural Soil Types
ABG1	0 - 5	6×10^4	7.61	0.34	0.038	0.28	26.3	1.721	0.117	0	2.5	0.5	19	23	59	Sandy loam
ABG2	5 - 15	1×10^4	7.51	0.242	0.042	0.40	23.8	0.966	0.106	0	1.5	0.5	11	6	83	Loamy Sand
ABG3	0 - 5	6.5×10^5	7.62	0.35	0.021	0.35	25.1	1.389	0.085	0.761	4.5	2	26	4	70	Sandy clay loam
ABG4	5 - 15	5×10^3	7.63	0.38	0.028	0.19	22.5	0.936	0.124	1.169	3.5	2	20	1	80	Sandy clay loam

Micrococcus roseus. Actinomycetes spp. have highest frequency in the three studied sub-regions and next are *Streptomyces* spp.

Total bacterial count of different soil samples from AL-Gaeli region are presented in Table 4. The diversity of soil microorganisms of the study habitat is presented in Table 5. The correlation effects between the soils parameters on bacterial count were studied (Table 6 and Table 7).

The Relationship between the soil physico-chemical properties and the viable bacterial count (cfu·g^{-1} soil) in AL-Gaeli region

The correlation effects between the soil parameters on bacterial count were studied.

1) Kunger sub-region:

Total bacterial count was positively correlated (p = 0.05) with P (r = 0.9876), sand (r = 0.6254), K (r = 0.607), Ca (r = 0.6133), Mg (r = 0.5644), OC (r = 0.4471), EC (r = 0.321) clay (r = 0.0637) and N (r = 0.0274) and negatively correlated (p = 0.05) with pH (r = −0.0907), silt (r = −0.6772) and SP (r = −0.9844). Table 6.

2) Gary sub-region:

Total bacterial count was positively correlated (p = 0.05) with pH (r = 0.5513), sand (r = 0.4464), K (r = 0.6784), EC (r = 0.70), Na (r = 0.5269), Ca (0.03506), Mg (r = 0.06022) and OC (r = 0.4349) and negatively correlated (p = 0.05) with clay, silt, SP, P and N. Table 7.

3) WadiAb-Gadad sub-region:

The sample size is too small to allow a reliable calculation of the Pearson Correlation Coefficient.

All the relationships between the total viable bacterial counts and soil physico-chemical properties or plant species are compiled in Table 6 and Table 7. There were obvious differences in correlation coefficients among the selected criteria (65% from the total number of correlation coefficients were positively correlated between bacterial counts and soil physico-chemical properties.

Our results showed that microbial population was different in soil under different plant covers, soil types and depths. The total number of isolated bacteria varied in different samples of studied soils.

The higher bacterial counts CFUs observed in the *Calotropis procera* and *Acacia tortilis* ssp. rhizospheres (8.5×10^5) at surface layer of soil in Kunger sub-region and in *Panicum turgidum* rhizosphere (7.5×10^4) at sub-soil of Gary

Table 4. Total bacterial count of different soil samples from AL-Gaeli region.

Sample No.	Plant	Soil Depth	Bacterial count (CFU/g)	Type of bacteria isolated
KUN1	*Capparis decidua*	0 - 5	8.5×10^5	*Bacillus circulans* *Bacillus cereus* *Actinomyces* spp. *Streptomyces* spp.
KUN2	*Capparis decidua*	5 - 15	3×10^4	*B. lentus* *B. circulans* *B. cereus* *Actinomyces* spp. *Streptomyces* spp.
KUN3	*Acacia tortulis* ssp. *Samur*	0 - 5	8.5×10^5	*B. lentus* *B. circulans* *B. cereus* *Actinomyces* spp. *Streptomyces* spp.
KUN4	*Acacia tortulis* ssp. *Samur*	5 - 15	1.2×10^5	*B. lentus* *B. circulans* *B. subtilis* *B. cereus* *Actinomyces* spp. *Streptomyces* spp.
KUN5	*Calotropis procera*	0 - 5	1.1×10^4	*B. circulans* *B. subtilis* *B. cereus* *Actinomyces* spp. *Streptomyces* spp.
KUN6	*Calotropis procera*	5 - 15	1.5×10^5	*B. lentus* *B. subtilis* *Micrococcus roseus* *Actinomyces* spp. *Streptomyces* spp.
GAR1	*Panicum turgidum*	0 - 5	1.7×10^2	*B. lentus* *B. cereus* *Micrococcus roseus* *Actinomyces* spp. *Streptomyces* spp.
GAR2	*Panicumturgidum*	5 - 15	7.5×10^4	*B. lentus* *Micrococcus varians* *Actinomyces* spp. *Streptomyces* spp.
GAR3	*Acacia ehrenbergiana*	0 - 5	1.5×10^4	*B. cereus* *B. badius* *B. pantothenticus* *Actinomyces* spp. *Streptomyces* spp.
GAR4	*A. ehrenbergiana*	5 - 15	7.5×10^3	*B. cereus* *Actinomyces* spp. *Streptomyces* spp.
GAR5	*Leptadenia pyrotechnica*	0 - 5	1.2×10^5	*B. lentus* *B. cereus* *Actinomyces* spp. *Streptomyces* spp.

Continued

GAR6	*Leptadenia pyrotechnica*	5 - 15	1.6×10^4	*B. badius* *Actinomyces* spp. *Streptomyces* spp.
ABG1	*Balanites aegyptiaca*	0 - 5	6×10^4	*B. lentus* *B. circulans* *Actinomyces* spp. *Streptomyces* spp.
ABG2	*Balanites aegyptiaca*	5 - 15	1×10^4	*B. badius* *Actinomyces* spp. *Streptomyces* spp.
ABG3	*Acacia tortilis* ssp. *Radiana*	0 - 5	6.5×10^5	*B. lentus* *B. subtilis* *Actinomyces* spp. *Actinomyces* spp. *Streptomyces* spp.
ABG4	*Acacia tortilis* ssp. *Radiana*	5 - 15	5×10^3	*B. cereus* *B. lentus* *Actinomyces* spp. *Streptomyces* spp.

Table 5. Diversity of microorganisms in the study area.

Sub-region	Shannon-Weiner Diversity Index	Simpson Diversity Index
Kunger	1.328	2.322
Gary	1.306	2.2115
WadiAb Gadad	0.4580	1.21

Table 6. Correlation coefficients of the physico-chemical properties with the viable bacterial count (cfu·g^{-1} soil) in Kunger sub-region.

Soil Physico-chemical Properties	R	R^2	Correlation
pH	−0.0907	0.0082	−ve
EC	0.3212	0.1032	Weak +ve
Clay	0.0637	0.0041	Weak +ve
Silt	−0.6772	0.4586	−ve
Sand	0.6254	0.3911	Moderate +ve
SP	−0.9844	0.969	−ve
Na	−0.4419	0.1953	−ve
K	0.607	0.3684	Moderate +ve
P	0.9876	0.9754	Strong +ve
Ca	0.6133	0.3761	Moderate +ve
Mg	0.5644	0.3185	Moderate +ve
N	0.274	0.0751	Weak +ve
O.C	0.4471	0.1999	Weak +ve

Correlation: strong +ve = 0.8 - 1.0; moderate +ve = 0.3 - 0.7; weak +ve = less than 0.3; negative = −ve (SPSS).

sub-region. This could be to better availability of nutrients and environmental conditions which favored their growth.

Table 7. Correlation coefficients of the physico-chemical properties with the viable bacterial count (cfu·g^{-1} soil) in Gary sub-region.

Soil Physico-chemical Properties	R	R^2	Correlation
pH	0.5513	0.3039	Moderate +ve
EC	0.7	0.49	Moderate +ve
Clay	−0.5319	0.2829	Moderate –ve
Silt	−0.3414	0.1166	–ve
Sand	0.4464	0.1993	+ve
SP	−0.2134	0.0455	–ve
Na	0.5269	0.2776	Moderate +ve
K	0.6784	0.4602	Moderate +ve
P	−0.3356	0.1126	Weak –ve
Ca	0.3506	0.1229	Weak +ve
Mg	0.6022	0.3626	Moderate +ve
N	−0.226	0.0511	Weak –ve
O.C	0.4349	0.1891	Weak +ve

Correlation: strong +ve = 0.8 - 1.0; moderate +ve = 0.3 - 0.7; weak +ve = less than 0.3; negative = –ve (SPSS).

In general, bacterial CFUs tend to decrease with increase in soil depth. Decrease in the bacterial CFUs with increasing soil depth in some cases could be related to the organic carbon content of the soil as nutrients are declining with the increase in soil depth. The higher bacterial CRUs at the surface layer might be due to the presence of litters, twigs, herbs and tree canopy which render a moist environment in the soil and favor high microbial activity and hence high microbial populations.

From the three sub-regions collected soils, five different textural soil classes (clay loam, sandy clay loam, loam, sandy loam and loamy sand) were detected. The data of soil pH values showed some differences among different soil textures. In study region, the lowest value (pH = 7.24) was recorded in sandy clay loam and the highest one (pH = 7.78) in clay loam. The highest value of soil organic carbon content were recorded in the texture soils (sandy loam, clay loam and sandy clay loam) whereas the lowest contents were in clay loam and sandy clay loam at sub-surface layer. These differences were documented previously by Silver *et al*., (2000) [17], who found that soil texture plays a key role in below ground C storage in soil ecosystems and strongly influences nutrient availability and retention, particularly in fine textural soils. Matus *et al*., (2008) [18] observed that soil organic carbon tends to be associated with the fine fraction of soils and it was significantly three times in clay-rich soils than coarse soils. Fine texture soil shows more stable aggregates, which in turn may act as a media of greater amount of organic carbon and total nitrogen contents (Raiesi, 2006) [19]. Based on the results, it appears that microbial biomass is influenced by soil texture.

4. Conclusions

Qualitative analysis of microorganisms isolated from the studied soil samples

reveal a total of 8 different species of bacteria, of which 2 are unidentified. The 6 species are classified under *Bacillus* genera and the remaining 2 species are classified under *Micrococcus* genera.

The quantitative analysis of the isolated microorganisms was also carried out by considering individual colonies as separate units (CFUs). The quantitative data on microbial population recorded in the present study was analyzed using two diversity indices. High Shannon-Weiner diversity Index value for bacteria was obtained in Kunger sub-region (1.328) followed by Gary sub-region (1.306) and then WadiAb-Gadad sub-region (0.4580).

Soil *Actinomyces* spp. and *Streptomyces* spp. were the most abundant microorganisms identified in the three habitats (sub-regions) which directly may influence decomposition processes and nutrient cycling in the soil.

There are little variation in the occurrences of microorganisms in the studied sub-regions in terms of abundance and diversity. There is a need for greater understanding of physical, chemical, biochemical and biological factors influencing abundance and diversity on microbial habitats. Current biotechnology research is needed for developing new microbial pesticides from these studied microorganisms. The formulation of an appropriate national strategy in biotechnology should constitute an important, initial step towards the utilization and industrialization of microorganisms.

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