International Journal of Scientific World, 4 (1) (2016) 4-10

International Journal of Scientific World

Website: www.sciencepubco.com/index.php/IJSW
doi: 10.14419/ijsw.v4i1.5482
Research paper

Effect of soil physico-chemical properties and plant type on bacterial diversity in semi- arid parts in central Sudan. Part ii. Sharq El-neel region, Khartoum state

Hayat Ibrahim Hassan, Hatil Hashim El-Kamali*

Department of Botany, Faculty of Science and Technology, Omdurman Islamic University, Omdurman, Sudan
**Corresponding author E-mail:hatilhashim@gmail.com*

Abstract

Total viable counts of bacteria and bacterial diversity of the different soil samples from three different localities in Sharq EL-Neel region: Soba, AL-Aelafoon and Um Dawan Ban sub-regions were carried out. Soil physical and chemical characteristics (pH, EC,SP,solublecations: 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 thirteendifferent species of bacteria, of which two are unidentified. The ten species are classified under Bacillus genus. In Sharq EL-Neel regionsoil samples, total bacterial counts ranged from 9.5×10^4 cfu g^{-1} to $1{\times}10^3$ with a mean of $4{\times}10^3$ cfu g^{-1}. The quantitative data on microbial population recorded in the present study was analysed using two diversity indices. High Shannon-Weiner diversity Index value for bacteria was obtained in AL-Aelfoon sub-region (1.79361), whereas high Simpson's index value was obtained in Um Dawan Ban sub-region (2.80).ActinomycesActinomyces spp. and Streptomyces spp. Where the most abundant microorganisms identified in the three sub-regions. Total bacterial count in Soba soil was positively correlated with pH (r= 0.0194) and sand (r= 0.3205); the total bacterial count in AL-Aelafoon soilwas positively correlated with EC (r= 0.1062), clay (r= 0.3816), silt (r= 0.1936), SP (r= 0.9302), K (r= 0.6252), Ca (r= 0.0015) and Mg (r= 0.1556), whereas the total bacterial count in Um Dawan Ban soil was positively correlated with clay (r= 0.2614), silt (r= 0.0216), SP (r= 0.565), K (r= 0.9645), P (r= 0.0197), Ca (r= 0.7377), Mg (r= 0.0267), N (r= 0.5215) and O.C (r= 0.3214). There were obvious differences in correlation coefficients among the selected criteria (46 % from the total number of correlation coefficients were positively correlated between bacterial counts and soil physico-chemical properties whereas 54% from the total number were positively correlated between plant type and bacterial counts).

Keywords: *Microbial Diversity; Physico-Chemical Properties; Soils; Semi-Arid Zone; Sharq EL-Neel Region; Central Sudan.*

1. Introduction

Continuing our research works on the relationships between soil physico-chemical properties,plants and soil microorganism's populations in semi-arid parts in Sudan [1], we have study correlationsbetween theseparameters in Sharq EL-Neel region, Khartoum State, 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 [2]. 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: (1) soil texture and structure (2) nutrient status (3) soil pH (4) moisture and temperature (5) surface plants (6) Inputs and (7) compaction. Different soil environments will support different types and numbers of microorganisms. Different plant residues contain varying quantities and availability of carbon and nutrients. This influences the soil biological activity.

The objectives of this study were: (i) to obtain a better understanding of the correlations between microbial population and physico-chemical properties of different soil types in the study area. (ii) to study how plant type and soil type affects the microbial diversity and abundance. (iii) to explain the differences between the tested habitats.

2. Materials and methods

2. 1. Study site description and soil sampling

Soils were collected from three different sub-regions (Soba, AL-aelafoon and Um Dawan Ban sub-regions in the Khartoum State,in arid/semi-arid parts in Central Sudan. Soil samples were collected from 0 – 5cmand 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.

2.2. Bacteriological analysis

Nutrient agar medium was used for the enumeration of bacteria present in soil samples [3]. The pH was adjusted before addition of agar and sterilization. Serial dilution plate technique was used for the isolation of microorganism. One gramsoil sample was diluted (1: 100) with 100ml distilled water in a sterile conical flask and shaken well. One ml of this suspension was transferred to 9ml 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 48h 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.

2.2.1. Tests

Motility test was determined according to Cruickshank et al, 1975 [4].Catalase Catalase test Oxidation-Fermentation test (O/F), Oxidase test,Sugar fermentation test,Voges-Proskauer test,Nitrate reductiontest, Indole production test,Urease test,Citrate utilizationwere determined according toBarrow and Feltham 1993 [5]. Casein hydrolysis was determined by method described by Williams and Cross, 1971 [6]. .Starch hydrolysis was performed according to Collins et al., 1995 [7]. Total a viable count of bacteria was determined [8].

2.2.2. Isolation of Streptomyces

Isolation of Streptomyces was performed by the soil dilution plate technique [9]. In this technique; 1g of each soil sample was taken in 9ml of sterilized distilled water in pre-sterilized test tube. Serial aqueous dilutions (10^{-2}-10^{-7}) were prepared by transferring 1ml of the soil suspension into 9ml of sterilized distilled water in sterilized test tubes. Different aqueous dilutions (10^{-4}-10^{-6}) of the soil suspensions were applied separately into sterilized Petri-dishes and 20ml 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 10g soluble starch, 2g dipotassium hydrogen ortho-phosphate, 2g potassium nitrate, 2g sodium chloride, 4g casein, 0.05g hydrated magnesium sulphate, 0.1g calcium carbonate; 0.01g hydrated ferric sulphate, 15g agar in one liter of distilled water. The medium was sterilized by autoclaving 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 4ºC onto slants of $SCKNO_3$ medium until further examinations.

2.3. 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 [10]. Organic carbon content of the soil was determined by Wakely and Black method(Cited by Moghimi et al., [11]. Total nitrogen (%) was determined by Kjeldahl method following extraction from 2g soil with conc. H_2SO_4.The particle size analysis was carried out by the Pipette method(Cited by Moghimi et al., 2013 [11].
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 [12].

2.4. 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: $D= 1 -\sum_{i=1} S(P_i)^2$

Where: D is theindex 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 [12].

2.5. Statistical analysis

Correlation coefficient was performed in order to detect the relationships between soil physic-chemical parameters and microbial populations [13].

3. Results and discussion

3.1. The soil characteristics in Shaq EL-Neelregion

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 differentstudied sub-regions are presented in Tables 1-3.

Table 1: Some Soil Physico- Chemical Properties of Different Samples from Sharq EL-Neel Region- Soba Subregion

Sample No.	Soil Depth	Bacterial count (CFU/g)	pH	EC	N %	O.C %	SP	Na	K	P	Ca	Mg	Clay %	Silt %	Sand %	Textural Soil Types
SO1	0-5	$1X10^4$	7.71	0.53	0.056	0.47	26.3	3.019	0.076	1.482	2	0.75	30	17	53	Sandy clay loam
SO2	5-15	$5X10^3$	7.63	0.88	0.035	0.32	28.4	6.431	0.047	1.729	1.5	0.5	34	25	41	Clay loam
SO3	0-5	$1.5X10^3$	7.70	0.99	0.105	0.86	28.8	5.676	0.195	1.032	5	2.3	34	33	34	Clay loam
SO4	5-15	$1X10^4$	7.51	0.70	0.028	0.36	26.3	3.080	0.098	0	3	1.5	21	33	46	Loam
SO5	0-5	$1.7X10^4$	7.62	0.35	0.049	0.40	28.8	1.57	0.106	1.066	2	0.75	21	30	49	Loam
SO6	5-15	$1.4X10^3$	7.71	0.35	0.070	0.46	31.8	2.959	0.057	1.100	2.5	1	37	22	41	Clay loam
SO7	0-5	$1.5X10^5$	7.63	0.35	0.042	0.32	25.9	1.257	0	0	0	0	21	22	56	Sandy clay loam
SO8	5-15	$1.8X10^3$	7.49	0.35	0.049	0.61	25.1	1.419	0.096	1.872	4	1.5	19	25	56	Sandy loam
SO9	0-5	$1.8X10^3$	7.55	0.776	0.042	0.32	25.3	1.978	0.147	1.445	4	1.75	19	25	56	Sandy loam
SO10	5-15	$7.5X10^3$	7.71	0.367	0.049	0.48	27.7	2.478	0.041	1.623	2	0.5	24	17	59	Sandy clay loam

Table 2: Some Soil Physico- Chemical Properties of Different Samples from Sharq EL-Neel Region- AL-Aelafoon Subregion

Sample No.	Soil Depth	Bacterial count (CFU/g)	pH	EC	N %	O.C %	SP	Na	K	P	Ca	Mg	Clay %	Silt %	Sand %	Textural Soil Types
AL1	0-5	$1.2X10^{5}$	7.66	0.788	0.046	0.48	36.4	2.630	0.109	0	5	1.5	24	32	44	Loam
AL2	5-15	$1X10^{4}$	7.70	0.617	0.063	0.64	26.3	1.510	0.052	0.628	2.5	1	28	24	51	Sandy clay loam
AL3	0-5	$2.8X10^{3}$	7.73	0.40	0.063	0.72	22.1	0.804	0.119	0.628	4.5	1.5	22	34	44	Loam
AL4	5-15	$1.3X10^{3}$	7.69	0.37	0.042	0.63	30.1	1.963	0.039	1.031	2	0.75	20	27	54	Sandy loam
AL5	0-5	$1.2X10^{4}$	7.73	0.40	0.042	0.64	26.3	1.522	0.112	1.273	3	0.5	21	35	44	Loam
AL6	5-15	$1X10^{3}$	7.73	0.32	0.035	0.45	28.0	1.522	0.036	0	1.5	0.5	35	37	29	Clay loam
AL7	0-5	$1X10^{3}$	7.44	0.857	0.042	0.46	31.8	4.456	0.081	0	2.5	1.5	21	35	44	Silt loam
AL8	5-15	$1.1X10^{3}$	7.51	0.356	0.035	0.23	23.4	2.413	0.026	1.342	1.5	0.5	22	37	41	Loam
AL9	0-5	$2X10^{5}$	7.40	0.95	0.028	0.31	38.9	3.080	0.195	0.930	4.5	2	35	37	29	Clay loam
AL10	5-15	$7.5X10^{3}$	7.58	0.43	0.021	0.40	27.6	1.691	0.053	5.179	2	0.75	30	32	39	Clay loam
AL11	0-5	$1.2X10^{4}$	7.61	0.35	0.028	0.64	25.5	1.268	0.077	1.135	3	1	25	27	49	Loam
AL12	5-15	$1.6X10^{4}$	7.42	0.45	0.056	0.40	27.6	1.721	0.045	0.594	2.5	1	24	20	56	Sandy clay loam
AL13	0-5	$1.7X10^{4}$	7.36	2.00	0.035	0.45	25.5	4.63	0.178	0	20	4	35	27	39	Clay loam
AL14	5-15	$7.5X10^{3}$	7.69	2.434	0.035	0.46	27.5	12.05	0.104	0	19	4	20	39	41	Loam

Table 3: Some Soil Physico- Chemical Properties of different Samples from Sharq EL-Neel Region- Um Dawan Ban

Sample No.	Soil Depth	Bacterial count (CFU/g)	pH	EC	N %	O.C %	SP	Na	K	P	Ca	Mg	Clay %	Silt %	Sand %	Textural Soil Types
UD1	0-5	$4X10^{5}$	7.49	2.30	0.042	0.45	37.7	7.043	0.188	0	23	4	24	38	39	Loam
UD2	5-15	$4X10^{4}$	7.48	4.00	0.038	0.46	30.9	31.40	0.070	1.623	24	4	21	23	55	Sandy clay loam
UD3	0-5	$3X10^{5}$	7.70	0.44	0.056	0.61	31.4	1.956	0.154	0	2.5	0.5	19	13	69	Sandy loam
UD4	5-15	$9.5X10^{4}$	8.09	0.94	0.056	0.64	25.9	6.891	0.07	0	2.5	0.5	31	15	54	Sandy clay loam
UD5	0-5	$6.5X10^{5}$	7.81	1.12	0.07	0.65	30.9	5.405	0.224	1.412	5	1.50	35	19	46	Sandy clay loam
UD6	5-15	$3.5X10^{4}$	7.82	0.94	0.056	0.54	23.9	4.438	0.097	0.896	4	1	31	28	41	Clay loam

3.1.1. Soba sub-region

The soil of this sub-region is predominantly sandy clay loam. The pH of soil samples ranged from 7.49 to 7.71. The EC values varied from 0.35 – 0.99 mmohs/cm. The total nitrogen was in range 0.028 – 0.105. Organic carbon range between 0.32 and 0.86 %. C:N ratio range between 8:1 and 13:1. The SP ranged from 25.1 – 31.8 %. Sodium contents ranges between 1.257 and 6.431 Meq/L. As for K it varies between 0.0 and 0.195 Meq/L. Calcium contents was found to vary between 0.0 – 5.0 Meq/L. Magnesium contents was found to vary between 0.0 and 2.3 Meq/L.P contents ranged between 0.0 and 1.872 ppm.

3.1.2. Al-aelafoon sub-region

The soil of this sub-region is predominantlyclay loam. The pH of soil samples ranged from 7.36 to 7.73. The EC values varied from 0.32 – 2.434 mmohs/cm. The total nitrogen was in range 0.021 – 0.063. Organic carbon range between 0.23 and 0.72 %. C:N ratio range between 7:1 and 23:1.The SP ranged from 22.1 – 38.9 %. Sodium contents ranges between 0.804 and 4.63 Meq/L. As for K it varies between 0.026 and 0.195 Meq/L. Calcium contents was found to vary between 1.5 – 20 Meq/L. Magnesium contents was found to vary between 0.5 and 4.0 Meq/L.P contents ranged between 0.0 and 5.179 ppm.

3.1.3. Um dawan ban sub-region

The soil of this sub-region is predominantlysandy clay loam. The pH of soil samples ranged from 8.00 to 7.48. The EC values varied from 0.44 – 4.0 mmohs/cm. The total nitrogen was in range 0.038 – 0.07. Organic carbon range between 0.45 and 0.65 %.C: N ratio range between 9:1 and 12:1. The SP ranged from 23.9 – 37.7 %. Sodium contents ranges between 1.956 and 31.043 Meq/L. As for K it varies between 0.070 and 0.224 Meq/L. Calcium contents was found to vary between 2.5 – 23 Meq/L. Magnesium contents was found to vary between 0.5 and 4.0 Meq/L.P contents ranged between 0.0 and 1.623 ppm.

From the 30 collected soils, five different textural soil classes (sandy clay loam, clay loam, loam, sandy loam and silt loam) were detected (Tables 1 -3). The data of soil pH values range between 8.09 (in Um Dawan Ban) to 7.36 (in AL-Aelafoon) among different soil textures. Sandy clay loam (in Soba and Um Dawan Ban)and clay loam (in Soba and AL-Aelafoon) soils showed highest bacterial populations.

3.2.Bacterial diversity and total counts of different soil samples from study region:

The diversity of soil microorganisms of the study habitat is presented in Table 4. Thirteen organisms were isolated from collected soil samples; Actinomyces spp., Streptomyces spp., Bacillus lentus , Bacillus badius, Bacillus pantothenticus, Bacillus mycoides, Bacillus alvei, Bacillus circulans, Bacillus subtilis, Bacillus cereus, Bacillus marcerans , Bacillus thruingiensis,Micrococcus varians. Actinomycetes spp. have highest frequency in the three studied sub- regions and next are Streptomyces spp.

Bacteria species like Bacillus lentus, B.circulans, B. cereus, B. mycoides, B. badius, B. thuringensis, Actinomyces spp. and Streptomyces spp. were found in the three habitats. These species are habitat generalists and are well adapted to change in environmental conditions.

Table 4: Total Bacterial Count of Different Soil Samples from Sharq EL-Neel Region

Sample No.	Plant	Soil Depth	Bacterial count (CFU/g)	Type of bacteria isolated
SO1	*Acacia ehrenbergiana*	0-5	$1X10^4$	*B. lentus* *B. circulans* *Actinomycesspp* *Streptomyces spp*
SO2	*A.ehrenbergiana*	5-15	$5X10^3$	*B. cereus* *B.badius* *Actinomycesspp* *Streptomyces spp*
SO3	*Acacia tortilis ssp. Radiana*	0-5	$1.5X10^3$	*B. cereus* *B. subtilis* *Actinomycesspp* *Streptomyces spp*
SO4	*A.tortilis ssp. radiana*	5-15	$1X10^4$	*B. cereus* *B. pantothenticus* *Actinomycesspp* *Streptomyces spp*
SO5	*Capparis decidua*	0-5	$1.7X10^4$	*B. mycoides* *B. lentus* *B. circulans* *B. thuringiensis* *Actinomycesspp* *Streptomyces spp*
SO6	*C.decidua*	5-15	$1.4X10^3$	*B. mycoides* *B. thuringiensis* *B. lentus* *Actinomycesspp* *Streptomyces spp*
SO7	*Prosopis chilensis*	0-5	$1.5X10^5$	*B. mycoides* *B. thuringiensis* *B. lentus* *B. circulans* *Actinomycesspp* *Streptomyces spp*
SO8	*P.chilensis*	5-15	$1.8X10^3$	*B. mycoides* *B. thuringiensis* *B. pantothenticus* *B. cereus* *Actinomycesspp* *Streptomyces spp*
SO9	*Balanites aegyptiaca*	0-5	$1.8X10^3$	*B. mycoides* *B. thuringiensis* *B. pantothenticus* *B. circulans* *Actinomycesspp* *Streptomyces spp*
SO10	*B.aegyptiaca*	5-15	$7.5X10^3$	*B. mycoides* *B. lentus* *B. thuringiensis* *B. marcerans* *B. circulans* *Actinomycesspp* *Streptomyces spp*
AL1	*Acacia ehrenbergiana*	0-5	$1.2X10^5$	*B. mycoides* *B. lentus* *B. marcerans* *B. circulans* *Actinomycesspp* *Streptomyces spp*
AL2	*A.ehrenbergiana*	5-15	$1X10^4$	*B. mycoides* *B. lentus* *B. thuringiensis* *B. marcerans* *B. circulans* *Actinomycesspp* *Streptomyces spp*
AL3	*Calotropis procera*	0-5	$2.8X10^3$	*B. mycoides* *B. lentus* *B. thuringensis* *B. marcerans* *B. circulans* *Actinomycesspp* *Streptomyces spp*
AL4	*C.procera*	5-15	$1.3X10^3$	*B. mycoides* *B. cereus* *B. lentus* *B. thuringiensis* *B. marcerans* *B. circulans* *Actinomycesspp* *Streptomyces spp*

AL5	*Balanites aegyptiaca*	0-5	$1.2X10^4$	*B. mycoides* *B. cereus* *Actinomycesspp* *Streptomyces spp*
AL6	*B.aegyptiaca*	5-15	$1X10^3$	*B. mycoides* *B. thuringiensis* *B. marcerans* *Actinomycesspp* *Streptomyces spp*
AL7	*Capparis deciduas*	0-5	$1X10^3$	*B. lentus* *B. thuringiensis* *B. cereus* *B. mycoides* *Actinomycesspp* *Streptomyces spp*
AL8	*C.decidua*	5-15	$1.1X10^3$	*B.badius* *B. lentus* *B. mycoides* *B. marcerans* *Actinomycesspp* *Streptomyces spp*
AL9	*Acacia tortilis ssp. spirocarpa*	0-5	$2X10^5$	*B. mycoides* *B. lentus* *B. circulans* *B. thuringiensis* *B. marcerans* *Actinomycesspp* *Streptomyces spp*
AL10	*A.tortilis ssp. Spirocarpa*	5-15	$7.5X10^3$	*B. thuringiensis* *B.cereus* *B.mycoides* *Actinomycesspp* *Streptomyces spp*
AL11	*Ziziphus spina- Christi*	0-5	$1.2X10^4$	*B. thuringiensis* *B.cereus* *B.mycoides* *Actinomycesspp* *Streptomyces spp*
AL12	*Z. spina- Christi*	5-15	$1.6X10^4$	*B. thuringiensis* *B.cereus* *B.mycoides* *Actinomycesspp* *Streptomyces spp*
AL13	*Prosopis chilensis*	0-5	$1.7X10^4$	*B. thuringiensis* *B.cereus* *B.mycoides* *Actinomycesspp* *Streptomyces spp*
AL14	*P.chilensis*	5-15	$7.5X10^3$	*B. thuringiensis* *B.cereus* *B.mycoides* *Actinomycesspp* *Streptomyces spp*
UD1	*Acacia tortilis ssp. tortilis*	0-5	$4X10^5$	*B. thuringiensis* *B.cereus* *B.mycoides* *Actinomycesspp* *Streptomyces spp*
UD2	*A.tortilis ssp. tortilis*	5-15	$4X10^4$	*B. mycoides* *B. circulans* *B. lentus* *Actinomyces spp.* *Streptomyces spp.*
UD3	*Acacia tortilis ssp. radiana*	0-5	$3X10^5$	*B. mycoides* *B. circulans* *B.alvei* *B. lentus* *Actinomyces spp.* *Streptomyces spp.*
UD4	A.tortilis ssp. radiana	5-15	$9.5X10^4$	
UD5	Acacia ehrenbergiana	0-5	$6.5X10^5$	*B. cereus* *B. pantothenticus* *B. mycoides* *Micrococcus varians* *Actinomycesspp* *Streptomyces spp*
UD6	A.ehrenbergiana	5-15	$3.5X10^4$	*B. cereus* *B. pantothenticus* *B.alvei* *B. lentus* *B. mycoides* *Micrococcus varians* *B.badius* *Actinomycesspp* *Streptomyces spp*

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. Among several factors affecting microbial population and activity, moisture, temperature, nutrients and soil depth are important factors.

Bacterial count tends to decrease with increase in soil depth. Decrease in the bacterial count with increasing soil depth could be related to the organic carbon content of the soil as nutrients are declining with the increase in soil depth. The higher bacterial count 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 [14].

3.3. Quantitative data on microbial populations using diversity indices

The quantitative data on microbial population recorded in the present study was analysed using two diversity indices. High Shannon-Weiner diversity Index value for bacteria was obtained in AL-Aelfoon sub-region (1.79361), whereas high Simpson index value was obtained in Um Dawan Ban sub-region (2.80). Table 5.

Table 5: Diversity of Microorganisms in the Study Area

Sub-region	Shannon-Weiner Diversity Index	SimpsonDiversity Index
Soba	1.3453	1.78
AL-Aelafoon	1.79361	2.7213
Um Dawan Ban	1.5408	2.80

3.4. The correlation effects between the soils characteristics on bacterial count:

The correlation effects between the soils parameters on bacterial count were studied (Tables 6 - 8).

3.4.1.Soba

Total bacterial count was positively correlated with pH (r= 0.0194) and sand (0.3205) and negatively correlated with EC, clay, silt, SP, Na, K, P, Ca, Mg, N, and OC. Table 6.

3.4.2. AL-aelafoon sub-region

Total bacterial count was positively correlated with EC (r= 0.1062), clay (r= 0.3816), silt (r= 0.1936), SP (r= 0.8302), K (r= 0.6252), Ca (r= 0.0015), and Mg (r= 0.1556). Table 7.

3.4.3. Um dawan ban sub-region

Total bacterial count was positively correlated with clay (r= 0.2614), silt (r= 0.0216), SP (r= 0.565), K (r= 0.9645), P (r= 0.0197), Ca (r= 0.7377), Mg (r= 0.0267), N (r= 0.5215) and OC (r= 0.3214) and negatively correlated with pH, EC, sand and Na. Table 8.

All the relationships between the total viable bacterial counts and soil physico-chemical properties or plant types are compiled in Tables 6 - 8. There were obvious differences in correlation coefficients among the selected criteria (46 % from the total number of correlation coefficients were positively correlated between bacterial counts and soil physico-chemical properties whereas 54 % from the total number were positively correlated between plant type and bacterial counts).

Table 6: Correlation Coefficients of the Physico-Chemical Properties with the Viable Bacterial Count (Cfu G^{-1} Soil) In Soba Sub-Region

Soil Physico-chemical Properties	R	R^2	Correlation
pH	0.0194	0.0004	Weak +ve
EC	-0.332	0.1102	-ve
Clay	-0.2685	0.0721	-ve
Silt	-0.1444	0.0209	-ve
Sand	0.3205	0.1027	+ve
SP	-0.2621	0.0687	-ve
Na	-0.3722	0.1385	-ve
K	-0.5597	0.3133	-ve
P	-0.6273	0.3935	Moderate –ve
Ca	-0.6766	0.4578	Moderate –ve
Mg	-0.577	0.3329	Moderate –ve
N	-0.2104	0.0443	Weak –ve
O.C	-0.3295	0.1086	Weak –ve

Table 7: Correlation Coefficients of the Physico-Chemical Properties with the Viable Bacterial Count (Cfu G^{-1} Soil) in AL-Aelafoon Sub-Region

Soil Physico-chemical Properties	R	R^2	Correlation
pH	-0.3094	0.0957	-ve
EC	0.1062	0.0113	+ve
Clay	0.3816	0.1456	+ve
Silt	0.1936	0.0375	+ve
Sand	-0.4129	0.1705	-ve
SP	0.8302	0.6892	Strong +ve
Na	-0.0014	0	-ve
K	0.6252	0.3909	Moderate +ve
P	-0.0983	0.0097	Weak –ve
Ca	0.0015	0	Weak +ve
Mg	0.1556	0.0242	Weak +ve
N	-0.1926	0.0371	Weak –ve
O.C	-0.3388	0.1148	Weak –ve

Table 8: Correlation coefficients of the physico-chemical properties with the viable bacterial count (cfu g^{-1} soil) in Um Dawan Ban sub-region

Soil Physico-chemical Properties	R	R^2	Correlation
pH	-0.1219	0.0149	-ve
EC	-0.2512	0.0631	-ve
Clay	0.2614	0.0683	+ve
Silt	0.0216	0.0005	+ve
Sand	-0.1771	0.0314	-ve
SP	0.565	0.3192	Moderate +ve
Na	-0.4126	0.1702	-ve
K	0.9645	0.9303	Strong +ve
P	0.0197	0.0004	Weak +ve
Ca	0.7377	0.5442	Moderate +ve
Mg	0.0267	0.0007	Weak +ve
N	0.5215	0.272	Moderate +ve
O.C	0.3214	0.1033	Weak +ve

4. Conclusion

Qualitative analysis of microorganisms isolated from the studied soil samples reveal a total of thirteen different species of bacteria, of which two are unidentified. The ten species are classified under Bacillus genus, and one species is classified under Micrococcus genus.

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 analysed using two diversity indices. Soil Actinomyces spp. and Streptomyces spp. were the most abundant microorganisms identified in the three habitats.

Current biotechnolgy research is needed for developing new microbial pesticides from these studied microorganisms.

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