Microbial and Heavy Metals Qualities of Agricultural Soil of Tsafe Local Government Area in Zamfara State, Nigeria

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\textbf{ABSTRACT}

This research was carried out for six months, during which soil samples of the council area were analyzed. 25 aerobic heterotrophic bacteria (AHB), 15 non-symbiotic nitrogen fixing bacteria (NFB) and 10 fungi were isolated from the soil. The mean total count of aerobic heterotrophic bacteria (AHB) are $5.8 \times 10^6$ cfu/g, $5.83 \times 10^6$ cfu/g, $7.3 \times 10^6$ cfu/g, $7.4 \times 10^6$ cfu/g and $5.6 \times 10^6$ cfu/g of soil for Zone 1 (ZN1), Zone 2 (ZN2), Zone 3 (ZN3), Zone 4 (ZN4), and Zone 5 (ZN5). Similarly, the mean total count of non-symbiotic nitrogen fixing bacteria (NFB) in the soil were $5.1 \times 10^6$ cfu/g, $4.0 \times 10^6$ cfu/g, $5.7 \times 10^6$ cfu/g, $5.6 \times 10^6$ cfu/g and $4.5 \times 10^6$ cfu/g of soil for ZN1, ZN2, ZN3, ZN4, and ZN5 respectively. The mean total fungal count (TFC) recorded were $7.9 \times 10^2$ cfu/g, $16.6 \times 10^2$ cfu/g, $9.3 \times 10^2$ cfu/g, $7.2 \times 10^2$ cfu/g and $14.3 \times 10^2$ cfu/g of soil for ZN1, ZN2, ZN3, ZN4 and ZN5 respectively. Bacillus, Pseudomonas, Staphylococcus, Micrococcus, Klebsiella, Escherichia were the predominant bacteria recorded. Fungal specie isolated in the soil are; Aspergillus, Rhizopus, Mucor, Penicillium and Fusarium. Lead concentration in the soil was highest (11.3± 2.5mg/kg), followed by Iron (10.9± 0.5), Zinc (9.4± 2.1mg/kg), Chromium (7.8± 2.6mg/kg), Copper (7.2± 1.76mg/kg), Nickel (7.2± 1.98mg/kg), and Cadmium was lowest (6.8± 1.2mg/kg), Chromium (17.8± 2.0), Iron (12.5± 0.5), Lead (16.5±1.3), Nickel (15.0± 4.0), and Iron (14.8±1.1) were the dominant heavy metals in ZN 1, ZN 2, ZN 3, ZN 4, and ZN 5 respectively. Correlation results between the microbial counts and heavy metal concentrations revealed no general pattern of relationship between the variables in the soil.

Key Words: Aerobic heterotrophic bacteria; agricultural soil; heavy metals; microbial; nitrogen fixing bacteria.

\textbf{INTRODUCTION}

Microorganisms exist in large numbers in the soil as long as there is a carbon source for energy. Large number of bacteria exists, but because of their small size, they have a smaller biomass. Bacteria and Actinomycetes can tolerate more soil disturbance than fungal populations, so they dominate in tilled soils, while fungal and nematode populations tend to dominate in untilled or no-tilled soils [1]. Bacteria are generally less efficient at converting organic carbon to new cells. Aerobic bacteria assimilate about 5-10 percent of the carbon while anaerobic bacteria only assimilate 2-5%, leaving behind many waste carbon compounds and inefficiently using energy stored in the soil organic matter [1]. Fungi generally release carbon dioxide into the atmosphere and are efficient at converting carbon to form new cells [2]. The fungus generally captures more energy from soil organic matter as they decompose it, assimilating 40-55% of the carbon. Most fungi consume organic matter higher in cellulose and lignin, which is slower and tougher to decompose [1].

Heavy metals are a dangerous group of soil pollutants. The contamination by heavy metals causes a serious problem because they cannot be naturally degraded like organic pollutants and they accumulate in different parts of the food chain [3]. The contamination of soils by heavy metals is significant problem, which leads to negative influence on soil characteristics and limitation of productive and environmental functions. The soil microbial community has a fundamental role in the process of organic matter degradation and mineralization, which allows the recycling of nutrients [4]. Heavy metals affect the number, diversity and microbial activity of soil microorganisms. They can slow down speed of growth and reproduction of microorganisms in the soil [5]. Concern about heavy metals in soil derives not only for their toxicity to living organisms inhabiting soil but also for their immobilization within...
different organic and inorganic colloids, in the immobilized form they can persist for long time before being again available to living organisms including plants [5].

Bacterial species showed an impressive display of responses to metal ions [6]. Diverse bacterial groups had shown ability to cope with these toxic elements in a variety of environments. With respect to pollution control, these activities show promise with regard to mobilization of metals, designing of metal tolerant strains and metal bioremediation through the breeding of natural and engineered strains [7]. [6] reported that most bacteria isolated from soil were resistant to very high concentrations of heavy metals, regardless of whether or not the soils were contaminated with metals. Metal tolerant species are either inherently less sensitive to metal contamination, for example due to decreased functioning of nonspecific transport systems, or have developed resistance to metal toxicity. Fungal strains and species differ in their sensitivity to heavy metals and in the protection mechanisms involved. The toxicity of some heavy metals such as mercury, copper and nickel has been used for the development of anti-fungal wood preservatives [8]. Some heavy metals are essential for the fungal metabolism (e.g. Zinc) while others do not have any known role in metabolism (e.g. Pb and Cd). In recent years, Anka, Bukkuyum and Gummi Local Government areas of Zamfara state, Nigeria have experienced heavy metals contamination resulting from illegal mining of gold. One would want to know the level at which some agricultural soils in the State are contaminated, since heavy metal pollution of soil causes contamination of ground water and plants through transfer processes and can directly make impact on micro-biota, animal and human health. This will contribute information regarding the quality of agricultural soil in the area and to throw more light on the bacterial and fungal flora which may further be explored for potential bioremediation of heavy metals in the soil.

MATERIALS AND METHODS

Study Area
Tsafe Local Government (Fig. 1) is located in the Sudan Savannah zone of the central part of Zamfara State (Fig 2), Nigeria. It lies on 11°56′00″N 6°54′00″E. It has an area of 1,698 km² and a population of 266,008 [9]. The area is characterized by two climatic seasons: dry season (November – April) and rainy season (May – October). It also has mono-modal rainfall pattern ranging from 750-1000 mm with annual mean precipitation of 875 mm. The mean annual temperature is 30 °C. The vegetation as observed by [10] consists of short grasses forming a matrix for thorny shrubs. The inhabitants of the area are predominantly Hausa/Fulani whose major occupations are farming and animal rearing.

Experimental Design and Sample Collection
The study area was divided into five designated zones. Soil samples were collected from the five sampling zones. 60 soil samples were randomly collected from each of the locations for the period of the study from the depth of 0-20cm with the aid of soil Auger. The samples were bulked into sterile sample containers and transported to the laboratory for analysis. Samples were collected once every month for six months. Microbiological analysis of the soil samples were carried out according to the methods of [11][12]. The bacterial isolates were identified and characterized using standard biochemical tests [13]. The tests employed include; colonial, morphological characteristics, Gram stain, spore staining, starch hydrolysis, nitrate reduction, motility, catalase, methyl red, Voges-Proskauer, indole production, urease activity, H₂S and gas production, citrate utilization, glucose, sucrose, and lactose utilization tests. The fungal isolates were identified according to [14] based on the colour of aerial hyphae and substrate mycelium, arrangement of hyphae, conidial arrangement as well as morphology.

Heavy metals were analyzed using the method of EPA 3050B [15]. The heavy metals determined were Pb, Cd, Cu, Zn, Ni, Fe and Cr.

The physicochemical analysis of the soil samples collected was carried out using the methods of [16]. The parameters determined were; Particle size, pH, temperature, electrical conductivity (EC), cation exchange capacity (CEC), moisture content, organic carbon, nitrogen content, phosphorus, magnesium, potassium and calcium.

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Figure 1: Map of Tsafe Local Government Area of Zamfara State Showing the Sampling Zones (ZN)
RESULTS

The mean count of different microbial groups in the agricultural soil of the five sampling zones located in Tsafe Local Government Area of Zamfara State was presented in Fig. 3. The mean total count of aerobic heterotrophic bacteria (AHB) are 5.8x10^6 cfu/g, 5.8.3x10^6 cfu/g, 7.3x10^6 cfu/g, 7.4x10^6 cfu/g and 5.6x10^6 cfu/g of soil for Zone 1 (ZN1), Zone 2 (ZN2), Zone 3 (ZN3), Zone 4 (ZN4), and Zone 5 (ZN5). The total aerobic heterotrophic bacterial counts were highest in ZN3 and ZN4 while ZN1, ZN2, and ZN5 had low counts (Fig. 3). Total AHB counts increases steadily from May to August. Higher counts were recorded in August for ZN2, ZN3 and ZN5, whereas ZN1 and ZN4 recorded their highest counts in July. Counts were lowest in April throughout the sampling zones (Fig. 3).

Statistical analysis shows no significant difference (P>0.05) in the mean count of AHB from the five locations studied. However, it was observed that, there was significant difference (P≤0.05) in the total mean count of AHB between April and September.

Similarly, the mean total count of non-symbiotic nitrogen fixing bacteria (NFB) in the soil were 5.1x10^6 cfu/g, 4.0x10^6 cfu/g, 5.7x10^6 cfu/g, 5.6x10^6 cfu/g and 4.5x10^6 cfu/g of soil for ZN1, ZN2, ZN3, ZN4, and ZN5 respectively. A significant increase in NFB count was recorded from April to August for ZN1, ZN2, ZN3, and ZN5 with August witnessing the highest NFB count. Whereas ZN4 recorded a drop in counts from May to June, and steadily increases again with July recording the highest counts (Fig. 4). Statistical analysis showed no significant difference (P>0.05) in the mean counts of NFB from the locations under study. However, the monthly mean distribution of NFB differ significantly (P≤0.05) between April and September.

Fungal counts were in ZN1, ZN2, ZN3, ZN4 and ZN5 were shown in Figure 5. The mean total fungal count (TFC) recorded were 7.9x10^2 cfu/g, 16.6x10^2 cfu/g, 9.3x10^2 cfu/g, 7.2x10^2 cfu/g and 14.3x10^2 cfu/g of soil for ZN1, ZN2, ZN3, ZN4 and ZN5 respectively. The highest count was recorded in ZN2 in April and ZN5 in July, while the lowest
count recorded was at ZN1 and ZN4 in May. However, statistical analysis shows no significant difference (P ≥ 0.05) in the mean number of fungal counts between April and September.

The bacterial isolates were identified as species of *Bacillus*, *Pseudomonas*, *Staphylococcus*, *Micrococcus*, *Klebsiella*, *Escherichia*, *Enterobacter* each, *Proteus*, *Actinomycetes*, *Morganella*, *Serratia*, *Providencia* and *Salmonella*. *Bacillus* species had the highest frequency of occurrence (23.8%), followed by *Staphylococcus* (13.2%), and *Pseudomonas* (11.1%). *Salmonella* and *Enterobacter* had a very low frequency of occurrence (0.3% and 0.5%). Other isolates had frequencies of occurrence ranging from 1.5% to 10.3% (Table 2). ZN3 had the highest frequency of occurrence of isolates (23.4%), followed by ZN4 (20.8%) and ZN5 (19.5%), ZN1 (18.6%) and ZN2 (17.6%) in that order (Table 1). The frequencies of occurrence of the AHB isolates in relation to months of sampling revealed that the month of July had more bacterial isolates (19.4%) followed by June (18.4), August (18.2%), September (15.5%), May (15.2%) and the month of April (13.1%) recording the lowest number of AHB. Similarly, percentage occurrence of non-symbiotic nitrogen fixing bacteria in the soil was; *Bacillus* (37.6%), *Klebsiella*
(21.4%), \textit{Pseudomonas} (20%), \textit{Enterobacter} (7.1%), \textit{Azotobacter} (11.4%) and \textit{Azomonas} (2.3%). It was observed that Zone 3 (22.8%) had the highest number of non-symbiotic nitrogen fixing bacteria followed by Zone 1 (20.9%), Zone 2 and Zone 5 (20% each) then Zone 4 (16.2%) in that order (Table 2). In relation to months of the sampling, April and June (18.1% each) had the highest number of isolates, followed by July and August (17.7% each), September (14.3%) and May (13.8%) in that order. The percentage non-symbiotic NFB were shown to be more abundant in ZN 1 (87.9%) and lowest in ZN 2 (68.9%).

![Fig. 4: Percentage non-symbiotic NFB in the agricultural soil of the zones](image)

The Fungi isolated and identified in the soil were \textit{Aspergillus} (34.9%), \textit{Rhizopus} (22.2%), \textit{Mucor} (11.1%), \textit{Penicillium} (15.4%) and \textit{Fusarium} (16.2%). \textit{Aspergillus} was more frequently isolated followed by \textit{Rhizopus} while \textit{Mucor} was least frequently encountered. It was also observed that Zone 5 (23.4%) had the highest number of fungal isolates followed by Zone 3 (22.2%), Zone 1 (20.6%) and Zone 2(19.0%) and Zone 4 with the encountered (14.7%) in that order (Table 3). With relation to sampling months, September had the highest frequency of occurrence of fungal isolates (18.8%) followed by June (18.3%), August (17.9%), July (15.6%), May (14.7%) and April (13.4%) in that order. The texture of the soils was loamy sand, with sand being the dominant fraction (Table 4). The means pH values ranged from 5.4 to 7.0 with a mean value of 5.8. The samples from ZN1 had the highest pH of 6.8±0.3, whereas the samples from ZN2 had the lowest mean pH of 5.4±0.06. Electrical conductivity (EC) of the soil samples from the sampling site ranged from 0.23ds/m to 0.84ds/m. Samples from ZN1 had the maximum value of 0.84±0.008ds/m, similarly, 0.23±0.02 ds/m from ZN5 was the minimum EC value. Significant difference was observed ($P \leq 0.05$) after analysis. The mean values of percentage carbon in the soil were 0.31. Soils from ZN5 had the highest mean value of 0.50%, whereas the soil from ZN2 had the lowest mean value of 0.20%. Mean Total

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The mean heavy metal concentration for the various zones was presented in Table 5. The total mean concentration of Pb in the soils was 11.4mg/kg. Mean values of Lead was maximum in ZN3 with 16.5±1.3mg/kg and minimum in ZN5 with 11.4mg/kg. The mean values of exchangeable bases (K⁺, Na⁺, Ca²⁺, and Mg²⁺) in the agricultural soil are 0.86cmol/kg, 0.83cmol/kg, 0.37cmol/kg and 0.34cmol/kg respectively. The mean values of cation exchange capacity from the five soils were 4.86cmol/kg. The highest mean value of 7.28±0.2cmol/kg was obtained in ZN4 while the lowest value of 3.07±0.2 was recorded at ZN2. Statistical analysis revealed significant differences (P≤0.05) between the soils CEC. Soil moisture mean values for the soils under study ranged from 2.50-4.50%. Maximum mean values of 4.5±1.4% were obtained from ZN4 soil, whereas the minimum recorded was 2.5±1.4% obtained from ZN1 and ZN5 soil respectively. Statistical analysis of the data using ANOVA revealed no significant difference (P>0.05) in the moisture content of the soils.
ZN5 with a mean value of 4.3±1.2mg/kg. Statistical analysis using Analysis of Variance revealed significant differences (P<0.05) in the concentration of Lead between the five zones. The mean total concentration of Zinc in the Soil samples was 9.4mg/kg. Zinc concentration was highest in the ZN3 with a mean value of 15±1.0mg/kg and lowest in ZN1 at 5.7±2.0mg/kg. The total mean concentration of cadmium in the soils was 6.9mg/kg. Highest mean concentration of 10.0mg/kg was obtained at ZN2 and the lowest was 3.0mg/kg in ZN5. Statistical analysis showed no significant differences (P>0.05) between the values obtained. Similarly, the total mean values of Cu are 7.3mg/kg. Maximum Cu concentration was obtained at ZN5 with 11.8±6.0mg/kg with ZN1 having the lower mean concentration of 2.8±0.7mg/kg. Nickel had a mean total value of 7.2mg/kg. Ni was higher in ZN4 with a mean value of 15.0±4.0mg/kg and ZN5 having the lowest mean concentration of 4.4±1.6mg/kg. The total mean concentrations of 9.4mg/kg were obtained for Cr. Its concentration was highest in ZN1 at 17.8±2.4mg/kg and lowest at ZN5 with a mean value of 3.3±0.8mg/kg. Iron (Fe) had a total mean concentration value of 7.9mg/kg. Fe was highest in ZN1 with a mean value of 15.2±0.7mg/kg, whereas ZN3 had a minimum value of 5.0±0.5mg/kg. The correlation coefficient was also analyzed in order to understand the relationship between microbial count and heavy metal concentrations on one hand and non-symbiotic nitrogen fixing bacteria and percentage nitrogen on the other. Various significant correlations were recorded between the different quantitative variables. While some metal concentrations (Cadmium, Copper, Nickel, Lead, Zinc, Iron) in relationship to AHb counts were negatively correlated at ZN1, ZN2, ZN3, ZN4 and ZN5, Chromium showed weakly positive correlation (r=0.41) with AHb counts at ZN1(Table 6). Similarly NFB counts were majorly negatively correlated with the heavy metal concentrations in the sampling zones (Table 7). Furthermore, correlation coefficient between fungal counts of chromium (r=0.64) at ZN1 and iron (r=0.82) at ZN2 was strong (Table 8). This is in contrast to other metal concentration such as Pb (r=-0.61) at ZN1, (r=-0.76) at ZN3.

Relationship between percentage nitrogen and non-symbiotic NFB counts was positive at ZN1 (r=0.87), ZN2 (r=0.64), ZN3 (r=0.19), but negative and weakly positive at ZN4 (r=-0.12), and ZN5 (r=0.27) respectively (Table 9).

Table 4: Physicochemical properties of agricultural soil of Tsafe council Area

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.8±0.3c</td>
<td>5.4±0.06a</td>
<td>5.4±0.04a</td>
<td>5.9±0.08b</td>
<td>5.3±0.1a</td>
</tr>
<tr>
<td>C (%)</td>
<td>0.2±0.04b</td>
<td>0.2±0.02c</td>
<td>0.3±0.05d</td>
<td>0.2±0.04a</td>
<td>0.5±0.01e</td>
</tr>
<tr>
<td>N (%)</td>
<td>0.1±0.20a</td>
<td>0.03±0.008a</td>
<td>0.07±0.008a</td>
<td>0.07±0.04a</td>
<td>0.04±0.08a</td>
</tr>
<tr>
<td>P(mg/kg)</td>
<td>0.6±0.02b</td>
<td>0.54±0.02a</td>
<td>0.72±0.03b</td>
<td>0.66±0.06b</td>
<td>0.86±0.06c</td>
</tr>
<tr>
<td>K(mmol/kg)</td>
<td>0.54±0.05a</td>
<td>0.7±0.06bc</td>
<td>0.7±0.03b</td>
<td>1.4±0.19d</td>
<td>0.9±0.02c</td>
</tr>
<tr>
<td>Na(mmol/kg)</td>
<td>0.8±0.19a</td>
<td>0.6±0.05a</td>
<td>0.6±0.03a</td>
<td>0.76±0.34a</td>
<td>0.73±0.2a</td>
</tr>
<tr>
<td>Ca(mmol/kg)</td>
<td>0.3±0.1ab</td>
<td>0.3±0.06a</td>
<td>0.3±0.007a</td>
<td>0.36±0.09a</td>
<td>0.5±0.1b</td>
</tr>
<tr>
<td>Mg(mmol/kg)</td>
<td>0.3±0.3a</td>
<td>0.3±0.09a</td>
<td>0.2±0.08a</td>
<td>0.05±0.04a</td>
<td>0.7±0.1b</td>
</tr>
<tr>
<td>CEC(mmol/kg)</td>
<td>4.7±0.1c</td>
<td>3.0±0.2a</td>
<td>5.6±0.1d</td>
<td>7.2±0.2e</td>
<td>3.6±0.05b</td>
</tr>
<tr>
<td>EC(dS/m)</td>
<td>0.8±0.008d</td>
<td>0.53±0.01c</td>
<td>0.5±0.02c</td>
<td>0.36±0.03</td>
<td>0.2±0.02a</td>
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<tr>
<td>Temp(°C)</td>
<td>38.3±1.6a</td>
<td>38.3±1.6a</td>
<td>40.5±1.2b</td>
<td>38.6±0.8b</td>
<td></td>
</tr>
<tr>
<td>Moisture(%)</td>
<td>2.5±1.4a</td>
<td>4.9±0.6a</td>
<td>3.7±0.5a</td>
<td>2.5±1.1a</td>
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</tr>
<tr>
<td>Sand(%)</td>
<td>80.6</td>
<td>89</td>
<td>81.1</td>
<td>80.6</td>
<td>84.5</td>
</tr>
<tr>
<td>Silt(%)</td>
<td>13.5</td>
<td>6.7</td>
<td>8.7</td>
<td>11.6</td>
<td>13.5</td>
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<tr>
<td>Clay(%)</td>
<td>5.9</td>
<td>4.3</td>
<td>8.2</td>
<td>7.8</td>
<td>2</td>
</tr>
<tr>
<td>Soil type</td>
<td>Loamy Sand</td>
<td>Loamy Sand</td>
<td>Loamy Sand</td>
<td>Loamy Sand</td>
<td>Loamy Sand</td>
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</tbody>
</table>

Note: Means with similar letters do not significantly differ using Tukey LSD (P<0.05)

Table 5: Mean Heavy Metals Concentration in Agricultural Soil in the zones (mg/kg)

<table>
<thead>
<tr>
<th>Element</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>15.0±7.0b</td>
<td>6.3±1.2a</td>
<td>16.5±1.3b</td>
<td>14.7±1.5b</td>
<td>4.3±1.2a</td>
</tr>
<tr>
<td>Cd</td>
<td>7.7±1.2a</td>
<td>11.2±1.6a</td>
<td>6.7±1.0a</td>
<td>5.0±1.5a</td>
<td>3.8±0.7a</td>
</tr>
<tr>
<td>Cu</td>
<td>2.8±0.7a</td>
<td>10.8±5.0b</td>
<td>6.7±1.2a</td>
<td>4.3±0.7a</td>
<td>11.8±4.3b</td>
</tr>
<tr>
<td>Ni</td>
<td>6.5±0.15a</td>
<td>6.0±0.18a</td>
<td>4.4±0.8a</td>
<td>15.0±4.0b</td>
<td>4.3±1.6a</td>
</tr>
<tr>
<td>Zn</td>
<td>5.7±2.0a</td>
<td>7.2±2.0a</td>
<td>15.0±10.8b</td>
<td>12.3±2.0a</td>
<td>3.0±1.7a</td>
</tr>
<tr>
<td>Cr</td>
<td>17.8±2.0c</td>
<td>5.2±0.9a</td>
<td>8.2±0.9b</td>
<td>4.8±1.4a</td>
<td>3.3±0.8a</td>
</tr>
<tr>
<td>Fe</td>
<td>15.2±0.7c</td>
<td>12.5±0.5b</td>
<td>5.5±0.5a</td>
<td>6.5±1.0a</td>
<td>14.8±1.1c</td>
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</table>

Note: Means with similar letters in the same column do not differ significantly using Tukey LSD (P<0.05)
Table 6: Correlation between heavy metals and AHB count in the sampling zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>Cd</th>
<th>Cu</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
<th>Cr</th>
<th>Fe</th>
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<tbody>
<tr>
<td>Zone 1</td>
<td>-0.51*</td>
<td>-0.69*</td>
<td>-0.4*</td>
<td>-0.61*</td>
<td>-0.87*</td>
<td>0.43*</td>
<td>0.14</td>
</tr>
<tr>
<td>Zone 2</td>
<td>-0.53*</td>
<td>-0.56*</td>
<td>-0.28</td>
<td>0.08</td>
<td>-0.21</td>
<td>0.01</td>
<td>-0.83*</td>
</tr>
<tr>
<td>Zone 3</td>
<td>-0.05</td>
<td>-0.47*</td>
<td>-0.62*</td>
<td>-0.21</td>
<td>-0.03</td>
<td>-0.56*</td>
<td>-0.88*</td>
</tr>
<tr>
<td>Zone 4</td>
<td>-0.22</td>
<td>-0.89*</td>
<td>0.21*</td>
<td>-0.05</td>
<td>-0.87*</td>
<td>0.27</td>
<td>-0.19</td>
</tr>
<tr>
<td>Zone 5</td>
<td>0.04</td>
<td>0.52*</td>
<td>0.071</td>
<td>0.06</td>
<td>-0.03</td>
<td>-0.62**</td>
<td>0.11</td>
</tr>
</tbody>
</table>

*Significant at P≤0.05

Table 7: Correlation between heavy count in the zones metals and non-symbiotic NFB

<table>
<thead>
<tr>
<th>Zone</th>
<th>Cd</th>
<th>Cu</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
<th>Cr</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>-0.11</td>
<td>-0.36*</td>
<td>-0.44*</td>
<td>-0.46*</td>
<td>-0.56*</td>
<td>0.52*</td>
<td>-0.09</td>
</tr>
<tr>
<td>Zone 2</td>
<td>-0.66*</td>
<td>-0.61*</td>
<td>-0.17</td>
<td>0.11</td>
<td>-0.2</td>
<td>-0.34</td>
<td>-0.59*</td>
</tr>
<tr>
<td>Zone 3</td>
<td>0.01</td>
<td>-0.61*</td>
<td>-0.75*</td>
<td>-0.34*</td>
<td>-0.12</td>
<td>-0.36</td>
<td>-0.87*</td>
</tr>
<tr>
<td>Zone 4</td>
<td>-0.58*</td>
<td>-0.78*</td>
<td>0.08</td>
<td>0.24</td>
<td>-0.63*</td>
<td>0.62*</td>
<td>0.05</td>
</tr>
<tr>
<td>Zone 5</td>
<td>-0.32*</td>
<td>0.25*</td>
<td>-0.35*</td>
<td>0.05</td>
<td>0.01</td>
<td>-0.74</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

*Significant at P≤0.05

Table 8: Correlation coefficient between heavy metals and fungal count

<table>
<thead>
<tr>
<th>Zone</th>
<th>Cd</th>
<th>Cu</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
<th>Cr</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>-0.22</td>
<td>-0.65*</td>
<td>-0.68*</td>
<td>-0.6*</td>
<td>-0.73*</td>
<td>0.64*</td>
<td>-0.12</td>
</tr>
<tr>
<td>Zone 2</td>
<td>0.21</td>
<td>0.63*</td>
<td>0.5*</td>
<td>0.01</td>
<td>0.18</td>
<td>0.03</td>
<td>0.82*</td>
</tr>
<tr>
<td>Zone 3</td>
<td>-0.41*</td>
<td>-0.78*</td>
<td>-0.39*</td>
<td>-0.76*</td>
<td>0.41*</td>
<td>-0.05</td>
<td>-0.68*</td>
</tr>
<tr>
<td>Zone 4</td>
<td>0.15</td>
<td>-0.49*</td>
<td>-0.52*</td>
<td>-0.21</td>
<td>0.23</td>
<td>0.22</td>
<td>0</td>
</tr>
<tr>
<td>Zone 5</td>
<td>0.37*</td>
<td>0.89*</td>
<td>0.07</td>
<td>0.34*</td>
<td>0.02</td>
<td>-0.28</td>
<td>0.35*</td>
</tr>
</tbody>
</table>

*Significant at P≤0.05

Table 9: Correlation between % Nitrogen and non-symbiotic NFB count

<table>
<thead>
<tr>
<th>Zone</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient</td>
<td>0.87*</td>
<td>0.64*</td>
<td>0.193</td>
<td>-0.12</td>
<td>0.27*</td>
</tr>
</tbody>
</table>

*Significant at P≤0.05

DISCUSSION

In this study of microbial and heavy metal qualities of agricultural soil of Tsaf council area, aerobic heterotrophic bacteria were recorded as the highest occurring bacteria in the soil. This could be attributed to the tolerance of this group of bacteria to wide variations in soil properties, which prevailed in all the zones. It followed the same trend reported by [17] in the study of microbiological properties of soils in Eket, Nigeria. Even though some species of bacteria and fungi are common to all sampling locations, some were not. These differences may arise as a result of different agricultural practices in the zones. These results corroborate with that of [18][19] who reported variations in bacterial species presence due to cropping practices. The study showed significant difference (P≤0.05) in the number of counts during the experiments. This may not be unconnected with the seasonal changes witnessed in the course of the study between dry and rainy. [17] Reported similar results, where microbial counts were higher during wet season than in dry season in soils of Eket, Nigeria. Bacillus sp. was the dominant bacterial specie isolated in the study of AHB and NFB in the agricultural soil of the area (accounting for 23% and 37% respectively). This may be as a result of the ability of Bacillus sp. to withstand stress and varying environmental conditions because of its ability to form spores. It is also pertinent to note that Bacillus was ubiquitous and indigenous to the soil flora. This result was similar to that reported by [20][6][21][22] who identified Bacillus sp. as the dominant species isolated from top soil. In another report, [23] identified Bacillus sp. as the predominant isolate from a highly polluted soil. Other studies by [21] conducted on agricultural soil in Mauritius reported Bacillus sp., to be the commonest species of bacteria inhabiting the soil. The result is however in contrast to that reported by [24] who also identified Escherichia coli as the dominant specie isolated from top soil samples of Obafemi Awolowo University at Ile, Nigeria. Also [19] reported that Escherichia coli was the dominant specie in some top soil samples of some selected sites in Pakistan. Domination by E. coli in the later studies may be as result of fecal pollution and other human

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activities in the soils under study. Other bacteria in abundance in the agricultural soil which were identified in the study were *Staphylococcus* (13%), *Pseudomonas* (11.1%) and (20%) among NFB, *Klebsiella* (10%) and (21%) among NFB respectively. Presence of these bacterial species may be as a result of their ability to redirect their central metabolism to sequester nutrients, helping them to survive different types of environmental conditions. This is similar to the findings of [19][25] that identified these bacterial species in soil samples at different locations. *Aspergillus* was the dominant fungal species isolated in the study. *Aspergillus* is a saprotroph and widespread in nature, is typically found in soil and decaying organic matter. Its predominance in the agricultural soil may be as a result of frequent usage of compost as a source of fertilizer in the soil by the locals. The result is similar to that reported by [22][19] where *Aspergillus* was identified as the dominant fungal species isolated in a soil sample. Similarly, fungal population was less than that of bacteria irrespective of the sampling locations. The dominance of bacteria over fungi has been reported by the findings of [19][24] in their studies of soil samples from different locations. Predominance of bacteria population over that of fungi was also reported by [26] in the study of soils from waste collection sites in Port Harcourt City, Nigeria.

The texture of the soil was loamy sand, and do not vary in the sampling zones. The soils under study showed range of acidity to neutrality. Though pH range observed was favorable to the survival of microorganisms, it may likely cause some variations in the microbial population. This is because there was significant difference (P≤0.05) in the pH values of the soils from the different sampling sites. The results showed that moisture content was relatively high in some zones, although no significant difference (P>0.05) was observed between values. Previous work as reported by [27] showed moisture content can influence microbial populations and activity. Significant difference (P≤0.05) existed in the amount of organic carbon, phosphorus, potassium, calcium, magnesium, cation exchange capacity, electrical conductivity and temperature. Variations in microbial counts in the zones may be as a result of the differences in these soil nutrients as [28] reported that, availability of some nutrients helps to determine microbial population and incidentally the kinds and biochemical activities of microorganisms in the soil.

The total heavy metal concentrations analyzed in the soil samples were presented in Table 2. Their concentration in the soil varied considerably, statistical analysis showed significant difference (P≤0.05) between the values in the different sampling zones. The mean Lead level in the agricultural soil of the area was 11.0 mg/kg. The low levels of lead in the agricultural soil are not surprising because agricultural soils normally contain low background levels of Pb. Except for fertilizers and other soil amendments that may add small amounts of lead and other heavy metals which can build up over time, only contamination from industrial activities or byproducts can increase the natural levels of these metals in the soil. This value was less than that reported by [29] who studied levels of heavy metals in the soils of Dutsinma and Malumfashi towns. Another study by [30] reported similar results in the analysis of Lead concentration of agricultural soil around industrial sites in Niger State, Nigeria. Furthermore, the relatively low average content of lead obtained in this study, much as it represents insignificant exposure risks for now, there is possibility of increase in Pb levels with time. Other findings by [31][32] had reported that the extent of heavy metal pollution varied with age, particularly for Cu and Pb. Mean value of Cadmium in the agricultural soil was 7.0mg/kg. Its detection in the agricultural soil may be as a result of the use of cadmium containing fertilizers and compost heaps. The level of cadmium recorded in this study was below the soil guideline values and the USEPA standards. The value of cadmium in this study was less than reported by [33] in the study of soils along Kubani River in Zaria, Nigeria. Recorded data from present study indicates that copper was detected in the agricultural soil of the area with an average concentration of 7.0mg/kg. Copper compounds naturally settle and bind to water sediment or soil particles. Also, copper compounds occur in the soil as a result of anthropogenic activities. Result of this study was found to be lower than that reported by [33] in the study of soil along Kubani River in Zaria, Nigeria. Mean nickel concentrations recorded in this study were 7.0mg/kg. Low concentration of nickel of nickel may be as a result of the sandy nature of the soil as clay soil favor nickel concentration in soil. Nickel content of the soil was higher than that reported by [30] where no nickel was detected in the study of agricultural soils from industrial sites in Niger State, Nigeria. The mean concentration for Zinc in this study was 9mg/kg. Zinc is common substance that occurs naturally in the soil. Its low concentration in the soil may be as a result of absence of any mining activity around the agricultural soils. The value recorded in this study was similar to 10mg/kg reported by [30] but less than 42.4mg/kg reported by [34] in the study of Zn and Cu in surface soils of central Greece. Iron mean concentration in the agricultural soil was recorded to be 11.0mg/kg. Iron exists in all types of soil. This value was lower than that reported by [29] from soils in Dutsinma and Malumfashi areas of Katsina, Nigeria. Chromium mean value in the soil was 7.8mg/kg. Detection of chromium in the soil may be as a result of its immobile nature in the soil. The value obtained in this study was lower than that reported by [35], who recorded 21.6mg/kg in agricultural soils of Segura valley of Spain.
Results of the heavy metal analyses shows that Zone 3 recorded the highest concentration of Lead (16.0mg/kg) among the five sampling zones. This may be attributed to the use of pesticides, organic and inorganic fertilizers, and atmospheric deposition from natural sources. The value of Lead recorded in this study was less than the WHO’s threshold limit value (TLV) of 50mg/kg for Pb in soil. It was also less than that reported by [36] who recorded 515mg/kg for farm soils in Pb polluted local government areas of Zamfara state.

The dominant bacteria isolated from the zone where Lead was higher were Bacillus (5.2% and 8.5%) in both AHB and non-symbiotic NFB respectively. This may be attributed to the ubiquitous nature of these bacteria in the soil. It could also be related to the ability of Bacillus to withstand different environmental stresses. This is similar to the findings of [37][38] and during bioremediation experiments by [21][32][39][40] who reported Bacillus as the dominant bacteria isolated from heavy metal contaminated soils. Tolerance to Pb by bacteria in the zone may be as a result of intrinsic properties of the microorganism e.g. producing extracellular mucilage or polysaccharide or an impermeable cell wall. Likely in this type of environment, one of the most important factors that explains the presence or absence of a given population may well be the relationship that exists between the whole bacterial communities. This study points to several groups of metabolically active bacteria with capabilities that are adapted to contaminated environments. It suggests that some groups of bacteria isolated where the concentration was highest will have high potential for bioremediation and should be explored further.

Correlation results between the microbial counts and heavy metal concentrations revealed no general pattern of relationship between the variables in the soil. Most bacterial counts were negatively correlated with heavy metals concentrations in the soil. This may be attributed to the toxic nature of these metals. Some fungal counts showed strong positive correlation with chromium (r=0.64) and iron (r=0.82). This may be as a result of the adaptation of fungi to the environment which enable them to resist the toxic nature of these metals.

Table 5 showed the correlation result between the non-symbiotic NFB and percentage nitrogen in the soils of the sampling zones. Positive correlation was recorded at Zone 1 (r=0.87), Zone 2 (r=0.64), Zone 3 (r=0.19) and Zone 5 (r=0.27). This can be attributed to the capability of these non-symbiotic NFB in transforming atmospheric nitrogen into fixed nitrogen in the soil. It is significant to note that percentage nitrogen in ZN 1, ZN 2, and ZN 3 correlated (r=0.27). This can be attributed to the capability of these non-symbiotic NFB in transforming atmospheric nitrogen into fixed nitrogen in the soil. It is significant to note that percentage nitrogen in ZN 1, ZN 2, and ZN 3 correlated positively with the percentage non-symbiotic NFB in the soil of these zones. The abundance of the non-symbiotic NFB in these zones may have played a role in increasing the amount of total nitrogen.

The outcome of this study has been able to show the diverse types of bacteria and fungi isolated and identified from agricultural soils of Tsafe Local Government of Zamfara State, Nigeria. Although samples were collected from different zones of the area, the distinct types of bacteria and fungi isolated were generally similar, though occurring at different locations in the period of the study. Despite the fact that it is possible that a number of bacteria and fungi may be missed in this study, the isolates identified could be readily assigned dominant (e.g. Bacillus sp, Aspergillus sp). Although the level heavy metals of the soils studied were low, background knowledge of the sources, chemistry, and potential risk of toxic heavy metals in the soils is necessary. This knowledge will make it easier in employing bioremediation option in case of any possible future contamination by heavy metals. This will reduce associated risks with heavy metals, make the land resource available for agricultural production, and enhance food security.

CONCLUSION

The outcome of this study has been able to show the diverse types of bacteria and fungi isolated and identified from agricultural soils of Tsafe Local Government of Zamfara State, Nigeria. Although samples were collected from different zones of the area, the distinct types of bacteria and fungi isolated were generally similar, though occurring at different locations in the period of the study. Despite the fact that it is possible that a number of bacteria and fungi may be missed in this study, the isolates identified could be readily assigned dominant (e.g. Bacillus sp, Aspergillus sp). This study points to several groups of metabolically active bacteria with capabilities that are adapted to contaminated environments. It suggests that some groups of bacteria isolated where the concentration of metals was highest will have high potential for bioremediation and should be explored. Further research should be carried out on the field to determine the extent at which the indigenous micro-flora isolated from the soil can perform in bioremediation of lead and other heavy metals. This will provide the much needed foundation for evaluation of the ever changing and dynamic world of soil microorganisms and their relationship with heavy metals.

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