Evaluation of soil quality on the basis of chemical and microbial health for potential use in agriculture

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The present study is a comparison of chemical and microbial status of wheat cultivated and non-cultivated soil from different localities. Soil samples were collected randomly and tested for soluble salts, pH, electrical conductivity, sodium adsorption ratio and microbial population. Soil samples pH, mostly lied in range between 7.29-7.94 \([H^+]\). The electrical conductivity (EC) of all soil samples except selected wheat agriculture land, lies within the standard range, that is, <4 ds/l which shows that soluble salts are present in the soils. The specific absorption rate (SAR) value varies greatly in wheat agricultural land due to more adsorption of sodium by roots in rhizosphere. Agricultural land soil samples showed high level of salinity and toxicity as compare to other test samples. Cocci and rod shape bacteria were present in the all soil samples. It has been also found that all the soil samples sites have less pathogenic microbes and have less accumulated salts and toxin and can be used efficiently for other crops cultivation. Uncultivated land was suitable for wheat cultivation but wheat cultivated lands was diverging towards salinity which is quite alarming. Agricultural lands need some amendments for salinity.

**Key words:** Soil bacteria, electrical conductivity, specific absorption rate, soil mycoflora, soil pH, wheat field soil.

**INTRODUCTION**

Soil quality may be defined as the “capacity of the soil to function within ecosystem and land-use boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health” (Doran et al., 1996). Biochemical properties are indicators of soil quality reflecting its reaction with plant population for productivity. By and large, biochemical properties are associated to the biocycles of the diagnostic elements. These properties consist of growth and multiplication of soil microbes and nutrient absorbance by affecting activity of hydrolytic enzymes (Gil-Sotres et al., 2005). In Pakistan, wheat is grown in different cropping systems, such as, cotton-wheat, rice-wheat, sugarcane-wheat, maize-wheat, and fallow-wheat. Of these, cotton-wheat and rice-wheat systems together account about 60% of the total wheat area whereas rain-fed wheat covers more than 1.50 m ha area. The yield in irrigated area ranges from 2.5 to 2.8 tones per hectare depending upon soil quality and input application.

Soil chemistry is a parameter for predicting the fate, mobility and potential toxicity of contaminants in the soil habitat. Crops differ in their yield potential and in the amounts of nutrients that they remove from the soil. Therefore, the rate of nutrients applied must be adjusted to the nutrient demand of the crop. Soil microbial communities are also integrally involved in biogeochemical cycles and their activities are crucial to the productivity of terrestrial ecosystems. Microbial analysis can help in predicting what types of microbes are present in the soil for application of pesticides and fertilizers. Soil status enables us to better predict the fate and toxicity of contaminants and provide the knowledge to develop scientifically correct and cost-effective remediation strategies.

To date, only limited information exists on microbial diversity for soils under various types of land use. The present study is designed to investigate opportunity of cultivating wheat in various soil types by comparing the

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**Abbreviations:** SAR, Specific absorption rate; EC, electrical conductivity; EDTA, ethylenediaminetetraacetic acid; ESP, exchangeable sodium percentage.
**Table 1.** Soil sampling and texture.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Sample</th>
<th>Soil color</th>
<th>Sample texture</th>
<th>Land use system</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Botanical garden</td>
<td>Whitish brown</td>
<td>Silty loam</td>
<td>Natural vegetation</td>
<td>Saline soil patches not reported for any disease</td>
</tr>
<tr>
<td>2</td>
<td>Un-cultivated land</td>
<td>Light brown</td>
<td>Sandy clay loam</td>
<td>Wheat – fallow-vegetable/fodder</td>
<td>Not reported for any disease</td>
</tr>
<tr>
<td>3</td>
<td>Agricultural land (P.U)</td>
<td>Light brown</td>
<td>Sandy clay loam</td>
<td>Wheat- fodder Wheat</td>
<td>Not reported for any disease</td>
</tr>
<tr>
<td>4</td>
<td>Agricultural land (Kasur)</td>
<td>Light brown</td>
<td>Sandy loam</td>
<td>Wheat- rice-Wheat</td>
<td>Not reported for any disease</td>
</tr>
<tr>
<td>5</td>
<td>Fallow land</td>
<td>Light brown</td>
<td>Sandy loam</td>
<td>Wheat – fallow-vegetable/fodder</td>
<td>Not reported for any disease</td>
</tr>
<tr>
<td>6</td>
<td>Housing scheme</td>
<td>Slightly dark brown</td>
<td>Sandy clay loam</td>
<td>High fertile land previously following Wheat-fodder/vegetable - wheat system now kitchen gardening at vacant plots</td>
<td>Damp soil, not reported for any disease</td>
</tr>
<tr>
<td>7</td>
<td>Un lined Water course</td>
<td>Dark brown</td>
<td>Clay loam</td>
<td>Irrigation depths sanctioned water course which irrigates land with canal water</td>
<td>Not reported for any disease but used for irrigation to pu field</td>
</tr>
</tbody>
</table>

biochemical status and evaluating nutrient availability, microbial status as well as suitability for agricultural practice.

**MATERIALS AND METHODS**

**Samples collection**

Seven soil samples were used in the current standard for the analysis of soil and were collected randomly from different localities. A visible or suspected salt crust on the soil surface was sampled separately. In case of distinct stratification, samples were taken by horizons or layers. In the absence of profile development or distinct stratification, the surface sample was taken to a depth of 6 or 7" (Table 1).

**Land preparation scheme**

Plowing depth: 15-20 cm; seed sowing depth: 5-7 cm; irrigation interval: germination to seedling stage: 10 days. Seedling to vegetative: 25 days and reproductive stage as required maturity irrigation stopped.

**Preparation of soil paste and extract**

Soil sample of 200 gm was mixed with distilled water to make homogenized soil paste and rested the paste for 24 h. For soil extract, a blotter paper was placed in the plate of the soil paste extractor. Soil paste was placed on the blotter paper under the extractor plate and the machine was started. Soil extract was used for electrical conductivity, soluble ions detection (that is, Ca$^{2+}$, Mg$^{2+}$, K$^+$, CO$_3^{-2}$, HCO$_3$- and Cl$^{-}$) and pH value.

**Electric conductivity of soil sample**

Soil extract was placed in a 50 mL bottle, the conductivity cell was immersed in the solution and the conductivity value of each soil sample was calculated.

**Detection of ions**

Soluble ions, that is, CO$_3^{-2}$ and HCO$_3$- were evaluated by neutralization method. Soil extract (2 mL) was titrated against H$_2$SO$_4$ (N/100). For chloride ion, 2 mL extract was titrated against N/100 AgNO$_3$. Calcium and magnesium ions were detected by adding 1-3 drops of NaOH in the solution along with a small amount of NH$_3$, appropriate for 2 mL of soil extract. Mixture was titrated against ethylenediaminetetraacetic acid (EDTA). Green, blackish, bluish, green, green coloration appeared as end point. To test for magnesium ion only, 3 drops of buffer solution with 3-4 drops ereocrome black was added to 2 mL soil extract; this gave a crimson coloration. Mixture was titrated against N/100 EDTA. Purple coloration appeared as end point. Sulfate was calculated by subtracting the value of (CO$_3^{-2}$+ HCO$_3$-+Cl$^{-}$) from total ions.

$$\text{SO}_4^{2-} = \text{T.C- (CO}_3^{-2}+ \text{HCO}_3^{-1}+\text{Cl}^{-1})$$
**Reference crop**

In the present study, wheat is used as reference crop for considering land use potential in agriculture.

**RESULTS AND DISCUSSION**

The soil samples were analyzed under various parameters, that is, pH, EC, total cations and anions, SAR, and microbial status. Soil samples pH, mostly lied in range between 7.29-7.94 [H⁺] neutral soils, that is, soils are non-acidic, non-basic but slightly alkaline because of more Mg and Ca ions available (Table 3). Nutrients in soil are strongly affected by soil pH due to reactions with soil particles and other nutrients, so in fact the availability of many nutrients have been determined as a function of soil pH (Wright et al., 2009). The soil quality indicators at farm level for good productivity soils should have a pH below 5.5 generally, and have a low availability of calcium, magnesium, and phosphorus. At this low pH, the solubility of aluminum, iron and boron is high; and low for molybdenum. At pH 7.8 or more, calcium and magnesium are abundant (USDA, 1998). The texture of the bulk soil samples were clayey loam to sandy and rhizosphere soils have sandy loam texture. So such soils have greater root growth.

The EC of the all soil samples except selected wheat agriculture land, lies within the standard range, that is, <4 ds/l which shows that soluble salts present in the soils does not that much cause salinity and effect the uptake of nutrients by the plant root (Table 2). Neutral soluble salts adversely affect the growth of most crop plants. Saline soils have an electrical conductivity of the saturation soil extract of more than 4 ds/m at 25°C (Richards, 1954). Soil salinity has been found to reduce wheat yields usually when values of electrical conductivity are above 6 decisements per meter (dS/m) throughout the root zone (Ortiz-Monasterio et al., 2002). The total cations are more in sample of wheat cultivated lands that is 3.77 - 3.85 meq/L while in housing scheme soil sample, is less; may be these ions have been leached down by water. The CO₃²⁻ is comparatively low in housing scheme soil sample (Waksman, 1916). The Cl⁻ ion is low in water course (1.5 meq/L) and high in fallow land (7.0 meq/L).

Soil sodicity is usually measured with one of two indices; one is the SAR which give information on the comparative concentrations of Na⁺, Ca²⁺ and Mg²⁺ in soil solution and the second one is the exchangeable sodium percentage (ESP), which measures the degree to which the exchange complex is saturated with sodium (Rahimia et al., 2000). The SAR value was high in agricultural land of Punjab University (7.2) as compared to housing scheme that is (0.4) due to more adsorption of sodium by roots in rhizosphere (Table 3). It was because this land is irrigated by canal water, that more Na⁺ is present in the soil and SAR value increased. The agricultural lands of
Table 2. Soil pH, electrical conductivity and soil texture.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Sample</th>
<th>pH (logs)</th>
<th>Electrical conductivity dS/l</th>
<th>Soil structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Botanical garden</td>
<td>7.76</td>
<td>2.96</td>
<td>Silt loam</td>
</tr>
<tr>
<td>2</td>
<td>Uncultivated land</td>
<td>7.85</td>
<td>2.01</td>
<td>Sandy clay loam</td>
</tr>
<tr>
<td>3</td>
<td>Agricultural land (wheat)</td>
<td>7.94</td>
<td>3.85</td>
<td>Sandy clay loam</td>
</tr>
<tr>
<td>4</td>
<td>Agricultural land (wheat) kasure</td>
<td>7.83</td>
<td>3.77</td>
<td>Sandy clay loam</td>
</tr>
<tr>
<td>5</td>
<td>Agricultural land (fallow) kasure</td>
<td>7.92</td>
<td>1.85</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>6</td>
<td>Housing scheme</td>
<td>7.29</td>
<td>0.72</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>7</td>
<td>Water course</td>
<td>7.55</td>
<td>0.52</td>
<td>Sandy clay loam</td>
</tr>
</tbody>
</table>

Table 3. Chemical analysis of soil samples.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Sample</th>
<th>CO₂</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>HCO₃</th>
<th>K</th>
<th>Cl</th>
<th>SO₄</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Botanical garden</td>
<td>1.5</td>
<td>14</td>
<td>18</td>
<td>24</td>
<td>6.3</td>
<td>0.4</td>
<td>3.1</td>
<td>38</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>Uncultivated land</td>
<td>0.9</td>
<td>13.0</td>
<td>6.5</td>
<td>1.9</td>
<td>4.5</td>
<td>0.1</td>
<td>6.0</td>
<td>11.0</td>
<td>0.61</td>
</tr>
<tr>
<td>3</td>
<td>Agricultural land (wheat)</td>
<td>1.1</td>
<td>18.0</td>
<td>1.0</td>
<td>21.7</td>
<td>3.5</td>
<td>0.9</td>
<td>4.5</td>
<td>33.5</td>
<td>7.2</td>
</tr>
<tr>
<td>4</td>
<td>Agricultural land (wheat) kasure</td>
<td>0.4</td>
<td>17.5</td>
<td>3.0</td>
<td>9.8</td>
<td>3.5</td>
<td>0.6</td>
<td>3.0</td>
<td>19.9</td>
<td>6.5</td>
</tr>
<tr>
<td>5</td>
<td>Agricultural land (fallow) kasure</td>
<td>0.6</td>
<td>8.5</td>
<td>6.5</td>
<td>4.5</td>
<td>3.0</td>
<td>3.0</td>
<td>7.0</td>
<td>12.8</td>
<td>1.66</td>
</tr>
<tr>
<td>6</td>
<td>Housing scheme</td>
<td>0.2</td>
<td>3.5</td>
<td>1.0</td>
<td>0.6</td>
<td>4.0</td>
<td>0.3</td>
<td>4.10</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>7</td>
<td>Water course</td>
<td>0.7</td>
<td>4.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.5</td>
<td>0.1</td>
<td>1.5</td>
<td>0.7</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Kasur are irrigated by tube well and the SAR value is near to the agricultural lands of Punjab University. It was also observed that the pH of the agricultural land is high and it also affects the SAR of soil. It was also low in housing uncultivated land (0.61). The critical values for considering a soil sodic is 13 for SAR and 15 for ESP. All the soil sample has less SAR <10 so all are suitable for wheat crop.

Fertilizers and rain affect soil pH. Organic matter, soil texture, and soil microorganisms, are a few other factors that affect soil pH. Agricultural limestone normally is used to increase the soil's pH. Sulfur is normally used to lower the soil pH. But fertilizer and water normally change the soil pH more rapidly. Therefore, it is the soil microbial population which controls the productivity of these soils if other environmental factors (moisture, temperature) are suitable. In fact, fertilization of a soil represents our attempt to balance the competition between plants and soil microbes for available soil nitrogen. Nitrogen tied-up in microbial cells is not available for plants or other microbes until that tissue has been decomposed by other microbe (Soil biota, 2004).

Soil microbiological diversity, microbial biomass, and respiration are all influenced by intensity and diversity of cropping (Lupwayi et al., 1999). Soil quality can be assessed not only by the quantity, but the kind of microorganisms present in the soil. Bacteria that were mostly found in samples are gram -ve and endospore forming (Table 4). Impact of biological activities on soil productivity have been reported by several authors (Ananyeva et al., 1999; Technical Advisory Committee to the CGIAR, 1988).

Among soil organisms, fungi can be important in both the formation and stabilization of soil aggregates (Lynch and Bragg, 1985). The fungi, Aspergillus niger was present mostly in the soil samples but less in water course samples. Most of the fungi isolated, were Aspergillus sp., Fusarium sp., Penicillium sp., Mucor sp. and Rhizopus sp. (Table 4). Jensen (1912) was the first to attempt a synthesis of data on soil mycoflora. Fungal species such as, Penicillium, Mucor, Cladosporium, Fusarium and Rhizopus, Rhizoctonia solani, Gaeumannomyces graminis, Pythium, Rhizopus, Mortierella and Fusarium has also been reported from wheat field soil (Warcup, 1957).

**Conclusion**

It is concluded that cultivated lands status is diverging towards salinity condition which is quite alarming. There is a need to amend cultivated lands for wheat and future cropping. It has also been found that all the soil samples have less pathogenic microbes and have less accumulated salts and toxin and can be used efficiently for other crops cultivation. In general, there is slight difference between cultivated and uncultivated soils which can be overcome by good agricultural practice.

Soil fungal communities are impacted by the recent trend towards reduced-tillage agricultural systems. Reduced tillage has been thought to lead to increased disease pressures from fungal pathogens, as residues...
Table 4. Bacterial and fungal population in soil samples.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Sample site</th>
<th>Frequency</th>
<th>Bacteria (Gram +ve /-ve)</th>
<th>Fungal isolates</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Botanical garden</td>
<td>++</td>
<td>Cocci and rod (All gram –ve)</td>
<td>Aspergilus flavus, Mucor sp and Fusarium sp.</td>
<td>+++</td>
</tr>
<tr>
<td>2</td>
<td>Uncultivated land</td>
<td>+++</td>
<td>Cocci (All gram –ve)</td>
<td>Aspergilus niger and Penicilum sp.</td>
<td>+++</td>
</tr>
<tr>
<td>3</td>
<td>Agricultural land (wheat)</td>
<td>+++</td>
<td>Cocci (gram –ve) and rod (gram –ve and +ve)</td>
<td>Aspergilus flavus, Mucor sp, Aspergilus niger and Penicilum sp.</td>
<td>+++</td>
</tr>
<tr>
<td>4</td>
<td>Agricultural land (wheat)</td>
<td>++</td>
<td>rod (gram –ve and +ve) and Cocci (gram –ve)</td>
<td>Aspergilus niger</td>
<td>+++</td>
</tr>
<tr>
<td>5</td>
<td>Agricultural land (fallow)</td>
<td>+++</td>
<td>Cocci (gram –ve and +ve) and rod (All gram –ve)</td>
<td>Aspergilus niger and Aspergilus flavus</td>
<td>+++</td>
</tr>
<tr>
<td>6</td>
<td>Housing scheme</td>
<td>++</td>
<td>Cocci and rod (All gram –ve)</td>
<td>Mucor sp and Penicilum sp.</td>
<td>++</td>
</tr>
<tr>
<td>7</td>
<td>Water course</td>
<td>++</td>
<td>Cocci and rod (All gram –ve)</td>
<td>Aspergilus niger, Mucor sp and Aspergilus sp</td>
<td>++</td>
</tr>
</tbody>
</table>

containing pathogenic fungal propagules are not exposed to competing soil microflora (Mansoor et al., 2006). In this regards Zaitlin et al. (2004) reported a positive relationship between soil management strategies and microbial inoculum count.

REFERENCES

Jensen CN (1912). Fungus flora of the soil. New York State Agricultural Experiment.

Richards LA (ed.) (1954). Diagnosis and Improvement of Saline and Alkali Soils. Agriculture Handbook No. 60. USDA-ARS.