Soil is a central link in the chain of interconnected domains comprising the terrestrial ecosystem. As human population continue to increase, human disturbance of the earth’s ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. The practice of intensive cropping with hybrid varieties for boosting food production caused decline in the level of nutrients in the soil at which productivity of crops cannot be sustained.

Tea is one of the most popular and widely consumed hot beverages worldwide. It is mainly grown in Asia, Africa, South America, and around the Black and Caspian Seas. About 75 per cent of the world’s tea production is represented by four biggest tea producing countries viz., China, India, Sri Lanka and Kenya. Approximately 507,196 ha area of land is under tea cultivation in India, which is confined mainly to Assam, Himachal Pradesh, Kerala, Karnataka, Uttarakhand, Arunachal Pradesh, Meghalaya, Nagaland, Mizoram, Sikkim, Orissa, and Tripura (Jain, 1999). Himachal Pradesh has boast a large area of land dedicated to tea estate in its mid hills sub-humid zone (Sood, 2016).

Tea is a shade loving plant and prefers a warm, humid environment. Its roots penetrate upto 1.5 m soil depth. However, majority of the feeder roots lies up to 0.6 m depth. One tonne of tea leaves removes 40 kg nitrogen, 12 kg phosphorus and 24 kg potassium (Bonheure and Willson, 1992).

Average green leaf tea productivity in Himachal Pradesh is 800 kg ha⁻¹ which is much lower as compared to average production of India (1668 kg ha⁻¹) as well as of world (1143 kg ha⁻¹). The low productivity of tea in many states was attributed to poor soil health conditions (Anonymous, 2011). The soil health
problems generally arose as a result of long-term unscientific management choices.

**Materials and Methods**

Tea growing areas in Himachal Pradesh lies between 31°59'19" to 32°17'44" N latitude and 76°18'39" E to 76°46'14" E longitude. The study area is characterized on gently (3 to 5 %) to moderately sloping (10 to 15 %), fluvo-glacial terraces and steeply sloping (>25 %) hill slopes (Sood, 2016). Generally, soils of tea gardens occurring on hill slopes are medium in depth (50 to 100 cm), coarse-loamy and acidic to neutral in reaction and qualify for Entisols, while those of tea gardens on terraces are deep, coarse to fine loamy and acidic and qualify for Inceptisols and Alfisols (Sidhu et al., 1997). Tea growing areas of Himachal Pradesh were thoroughly traversed during December, 2017. Thirty-seven soil sampling sites/tea growers were selected randomly from Kangra and Mandi districts. Location of the selected sites has been described in Table 1.

To assess the soil health status of plantation crops, surface (0-0.30 m) soil samples were collected from each tea garden by following the methodology given by (Mishra et al., 2009). Soil sampling was done in the month of January to February, 2018. The soil samples collected were processed for laboratory determinations by following the standard procedures (Table 2).

**Results and Discussion**

The data related to soil physico-chemical and biological attributes presented under the following heads:

**Particle density**: The particle density in soils of tea gardens varied from 2.57 to 2.63 Mg m\(^{-3}\) with a mean value of 2.60±0.02 Mg m\(^{-3}\) in the surface soil. The lowest value (2.57 Mg m\(^{-3}\)) was recorded in Darang, Narghta and Ghaniyara (Table 3), whereas the highest (2.63 Mg m\(^{-3}\)) was recorded in Gugga Saloh-II, Bhawarna, Jeahru, Bindrabhan and Bundla-II. In sub-surface soils, the particle density in soils

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### Table 1. Location of the selected tea gardens

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>S.No.</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dugni</td>
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<td>Sidhbari</td>
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<td>Ahju</td>
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<td>7</td>
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<td>26</td>
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</tr>
<tr>
<td>8</td>
<td>Gugga Saloh-I</td>
<td>27</td>
<td>Lambapatta</td>
</tr>
<tr>
<td>9</td>
<td>Gugga Saloh-II</td>
<td>28</td>
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</tr>
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<td>Bhawarna</td>
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<td>Chauntra</td>
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<td>Chhatar</td>
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<td>19</td>
<td>Sidhpur</td>
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### Table 2. Analytical methods used for soil analysis

<table>
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<th>Parameter</th>
<th>Method</th>
<th>Reference</th>
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<tbody>
<tr>
<td>PD</td>
<td>Pycnometer method</td>
<td>Gupta and Dhakshinamoorthy (1980)</td>
</tr>
<tr>
<td>Porosity</td>
<td>Empirical method</td>
<td>Gupta and Dhakshinamoorthy (1980)</td>
</tr>
<tr>
<td>% WSA (&gt;0.6 m)</td>
<td>Wet sieving method</td>
<td>Ekwu et al. (2018)</td>
</tr>
<tr>
<td>EC</td>
<td>Conductimetric method</td>
<td>Jackson (1973)</td>
</tr>
<tr>
<td>Available nutrients: Ca &amp; Mg</td>
<td>Flame photometric method/ Atomic Absorption</td>
<td>Jackson (1973)</td>
</tr>
<tr>
<td>Microbial population</td>
<td>Standard plate count technique</td>
<td>Wollum (1982)</td>
</tr>
</tbody>
</table>
varied from 2.59 to 2.65 Mg m⁻³ with a mean value of 2.61±0.02 Mg m⁻³. The increasing trend of particle density in the subsurface soils was registered during the study. This might be due to higher soil organic matter content of surface soils in comparison to sub-surface soils, which lead to increase in the volume of soil without much effect on weight of soil, resulting in decrease in particle density of surface soil. The results were in consonance with the findings of Tolimir et al. (2020).

**Porosity**: Data pertaining to porosity in table 3 revealed that the soil porosity of tea gardens ranged between 40 to 58% with a mean value of 44±5% in the surface soil. The minimum porosity (40%) was recorded in Bhawarna, Jeahru and Bindrabhan, whereas the

<table>
<thead>
<tr>
<th>Site</th>
<th>PD (Mg m⁻³)</th>
<th>Porosity (%)</th>
<th>WSA (%)</th>
</tr>
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<td>Usthwar</td>
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<td>2.62</td>
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<tr>
<td>Bhadal Devi</td>
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<td>2.59</td>
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<td>Ghaniyara</td>
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</tr>
<tr>
<td>Mean ± SD</td>
<td>2.60±0.02</td>
<td>2.61±0.02</td>
<td>2.61±0.02</td>
</tr>
</tbody>
</table>

Note: S=surface, Sb=sub-surface
maximum (58%) was recorded in Narghota. In sub-surface soils, the porosity in soils varied from 39 to 56% with a mean value of 43±5%. While comparing surface vs. sub-surface soils, the porosity of subsurface soils was less than the surface soils. This might be due to higher compaction along with increasing bulk density with depth, which resulted in lower porosity in the sub-surface soils. Similar findings were reported by Pongmala et al. (2022) and Tolimir et al. (2020) who recorded depth wise decrease in porosity in soils.

Water stable aggregates: Data presented in Table 3 depicts the water stable aggregates in soils of tea gardens. In the surface soils, the

<table>
<thead>
<tr>
<th>Site</th>
<th>EC (µs cm⁻¹)</th>
<th>Exchangeable bases [cmol (p⁺) kg⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>Sb</td>
</tr>
<tr>
<td>Dugni</td>
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<tr>
<td>Ustheer</td>
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<tr>
<td>Oder</td>
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<td>160</td>
</tr>
<tr>
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<td>Gugga Saloh-I</td>
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<tr>
<td>Gugga Saloh-II</td>
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<td>120</td>
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<tr>
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<td>Alhilal</td>
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<td>Deogran</td>
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<td>Mean ± SD</td>
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</tbody>
</table>

Note: S = Surface, Sb = Sub-surface
water stable aggregates varied from 26 to 59% with a mean value of 43±8% in the surface soil, however in the sub-surface soil samples, the water stable aggregates ranged from 23 to 52% with a mean value of 38±8%. From the mean value of both surfaces, it was revealed that the the lowest value (25%) was recorded in Bhawarna, whereas the highest (56%) was recorded in Narghota, Higher water stable aggregates in soils might be due to higher organic matter content and enhanced microbial activity which secretes binding material during the decomposition process, giving rise to better structure and stable aggregates. The results were in consonance with the findings of Bless et al. (2022) and Baker et al. (2004).

Table 5. Distribution of biological soil attributes in tea gardens studied

<table>
<thead>
<tr>
<th>Site</th>
<th>Microbial population</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Bacteria (CFU x 10^6)</td>
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<td>S</td>
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<td>Tikka Balla</td>
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<td>Darang</td>
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<td>GuggaSaloh-I</td>
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</table>

Note: S = Surface, Sb = Sub-surface
**Electrical conductivity**: The electrical conductivity in soils of tea gardens varied from 70 to 190 µS cm\(^{-1}\) with a mean value of 118±36.5 µS cm\(^{-1}\) in the surface soil. The lowest value (70 µS cm\(^{-1}\)) was recorded in Chauntra, Gopalpur and Chowgan (Table 4), whereas the highest (190 µS cm\(^{-1}\)) was recorded in Salan and Sidhbari. In sub-surface soils, the electrical conductivity in soils varied from 100 to 230 µS cm\(^{-1}\) with a mean value of 151±35.2 µS cm\(^{-1}\). The increasing trends of electrical conductivity in the sub-surface soils were recorded during the study. This might be due to leaching of soluble salts from surface to sub-surface layers, which lead to their accumulation in the lower layers (Wani et al., 2017). These results are in agreement with the findings of soils Kumar et al. (2021), Singh et al. (2016), Muche et al. (2015) and Mahajan et al. (2007).

**Exchangeable Ca**: Data pertaining to exchangeable Ca in Table 4 revealed that the exchangeable Ca of tea gardens ranged between 1.2 to 3.8 cmol (p\(^{+}\)) kg\(^{-1}\) with a mean value of 2.6±0.7 cmol (p\(^{+}\)) kg\(^{-1}\) in the surface soil. The minimum exchangeable Ca (1.2 cmol (p\(^{+}\)) kg\(^{-1}\)) was recorded in Bhawarna (Table 1), whereas the maximum (3.8 cmol (p\(^{+}\)) kg\(^{-1}\)) was recorded in Sungal and Gopalpur. In sub-surface soils, the exchangeable Ca in soils varied from 1.3 to 4.2 cmol (p\(^{+}\)) kg\(^{-1}\) with a mean value of 2.8±0.8 cmol (p\(^{+}\)) kg\(^{-1}\). While comparing surface vs. sub-surface soils, the exchangeable Ca of subsurface soils were higher than the surface soils. This might be due to the leaching of basic cations from the surface soil to the sub-surface layer, which lead to their deposition in the sub-surface layer. Similar findings were reported by Wani et al. (2017) and Kirmani et al. (2013).

**Exchangeable Mg**: Data presented in Table 4 depicts the exchangeable Mg in soils of tea gardens. In the surface soils, the exchangeable Mg varied from 0.6 to 2.2 cmol (p\(^{+}\)) kg\(^{-1}\) with a mean value of 1.4±0.4 cmol (p\(^{+}\)) kg\(^{-1}\) in the surface soil, however in the sub-surface soil samples, the exchangeable Mg ranged from 0.7 to 2.4 cmol (p\(^{+}\)) kg\(^{-1}\) with a mean value of 1.5±0.5 cmol (p\(^{+}\)) kg\(^{-1}\). From the mean value of both surfaces, it was revealed that the the lowest value (0.6 cmol (p\(^{+}\)) kg\(^{-1}\)) was recorded in Bhawarna, whereas the highest (2.3 cmol (p\(^{+}\)) kg\(^{-1}\)) was recorded in Narghota. Higher exchangeable Mg in soils might be due to enhanced organic matter content, which released exchangeable nutrients from the exchange sites in soil upon decomposition of organic matter. The results were in consonance with the findings of Dar et al. (2013) and Sharma et al. (2005).

**Microbial Count**: Data pertaining to microbial count presented in Table 5. It was evident from data that bacterial population, in soils of selected tea gardens of Himachal Pradesh ranged from 72 to 99 CFU x 10\(^{6}\) in surface and 25 to 43 CFU x 10\(^{6}\) in sub-surface soil. Also, the fungal population ranged from 25 to 43 CFU x 10\(^{4}\) with mean value of 43 CFU x 10\(^{4}\) in the surface soil, whereas 14 to 38 CFU x 10\(^{4}\) in sub-surface soil. The actinomycetes population under different tea gardens varied from 41 to 68 CFU x 10\(^{5}\) in surface soil samples and 20 to 51 CFU x 10\(^{5}\) in sub-surface soil samples. The microbial population in the sub-surface soils drastically decreases, while comparing with the surface samples. This might be due to better aeration, moisture availability and higher organic matter content in the surface soil, which stimulate microbial population in the soil. Similar findings were reported by Raghukumar et al. (2001) and Krishna et al. (2012) who recorded depth wise decrease in microbial community in soils of Kerala.

**Conclusion**: Last of all, it is inferred that constant removal of nutrients from the soil in the tea gardens requires continuous fertilization to sustain fertility.
and productivity of the soil. The balanced nutrient application is essential approach in order to get optimum yield along with minimal cost. From the experimental data it is revealed that 0-0.30 m depth having higher physical and biological properties, whereas chemical properties showed lowered status as compared to 0.30-0.60 m in all tea gardens. These figures indicated that there is a considerable scope of improving soil health and thereby, increasing soil productivity by adopting scientific soil management practices in tea gardens.

References


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