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# Appraisal Biological Health Status of the Cultivated Lands of Varanasi District of Uttar Pradesh

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**Soil health indicators are needed that help farmers to understand the chain of cause and effect that links farm decision to ultimate productivity and health of plant and animals. No single indicator was universal in describing soil property change due to the cultivation. However, there was a significant correlation between soil physical, chemical and biological indicators, which validates the holistic approach to soil health management and the need to better understanding of the flow on effects of soil management decisions. The Indo-Gangetic plain of Varanasi district was selected for the study. 24 surface soil (0-15cm) samples were collected from the cultivated land in Varanasi district and analysed for pH, EC, available N, P, K content and biological health status of soil. 22 samples having the low organic carbon status and 2 samples are medium in organic carbon. The availability of nitrogen vary from 163 to 301 kg $ha^{-1}$, phosphorus ranges from 14.16 to 40.39 2 kg $ha^{-1}$, while range of potassium vary 112.0 to 1358 kg $ha^{-1}$. The Dehydrogenase activity of soil vary from 24.33 to 70.33 $\mu$g TPF $g^{-1}$ soil $day^{-1}$, urease activity of soil vary from 128.60 to 342.30 $\mu$g UH $g^{-1}$ soil $h^{-1}$, alkaline Phosphatase activity vary from 68.70 to 211.70 $\mu$g PNP $g^{-1}$soil $h^{-1}$, whereas acid Phosphatase activity from 57.30 to 162.30 $\mu$g PNP $g^{-1}$soil $h^{-1}$. The Soil microbial biomass carbon (SMBC) and soil respiration values of the soils vary from 90.60 to 321.30 mg C $kg^{-1}$ soil and 0.1992 to 0.5421 mg $CO_2$-C $g^{-1}$ soil $day^{-1}$. Microbial Population of bacteria, fungi and actinomycetes in the soils vary from 14.20-42.70, 6.70-32.70 and 9.30-31.30 CFU x $10^6$ $g^{-1}$ soil respectively.**

**Key words:** Nutrients availability; enzymatic activity; soil microbial biomass carbon; organic carbon; microbial Population.

Quality of people depends upon quality of food. Healthy food comes from healthy soil. Hence, soil health must be cared, maintained and sustained for present and future generations. Soil health is defined as the continued capacity of soil to function as a vital living system, but recognizing that it contains biological elements that are key to ecosystem function within land-use boundaries (Doran and Zeiss, 2000; Karlen *et al*., 2001). These functions are able to sustain biological productivity of soil, maintain the quality of surrounding air, water and environments, as well as promote plant, animal, and human health (Doran *et al*., 1996). Soil biological health is used in a generic sense to describe the properties, processes and potential of the soil system associated with dead and living organic materials. To improve the sustainability and environmental accountability of soil there is a need to develop a set of soil health indicators that integrate physical, chemical and biological soil properties. The indicators would allow research workers to improve soil health management practices. To improve soil management there is a need to develop a set of indicators that are able to quantify changes in soil properties and which can promote improved land management practices. Therefore, there is a need to study the soil health status for maintaining soil health sustainability. Soil health

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cannot be measured directly, but soil properties that are sensitive to changes in management can be used as indicators. No single indicator was universal in describing soil property change due to the cultivation. Biological indicators include measurement of micro and macro-organisms, their activities or functions. Concentration or population of earthworm, nematodes, termite, ants as well as microbial biomass, fungi, actinomycetes, or lichens can be used as indicators, because of their role in soil development and conservation; Nutrient cycling and specific soil fertility (Anderson T., 2003). Other biological indicators that have been widely studied are the chemical compounds or metabolic products of microorganisms, particularly enzymes such as cellulose, arylsulphatase, phosphatase, urease and dehydrogenase related to specific functions of substrate degradation or mineralization of organic N, S, or P. Soil enzymatic activity assays act as potential indicators of ecosystem. Therefore, Since, the biological health status of the soils of Varanasi districts is not available, therefore, keeping all above point in view, the present research work Biological health status of the cultivated soils in Varanasi districts of Uttar Pradesh was undertaken to point out the major biological health indicators to measure the biological health of soil, and an attempt was also made to correlation (r) between different variables observed in soil samples of district Varanasi.

## MATERIALS AND METHODS

### Study region

The study area represents the soils of Indo-Gangetic Plain of Varanasi. Geographically, the district Varanasi is situated in between $25^0$, 18¢ North latitude and $80^0$, 36¢ East longitude at an altitude of 80.71 meters above mean sea level. It is almost *indo-gangetic* alluvial belt in semi-arid to sub humid climatic zone of northern India.

### Sample collection and analysis

Surface soil of the cultivated land of Varanasi districts were sampled randomly to a depth of 0-15 cm from 24 sites of different geo-morphological locations.. The entire samples were dried at room temperature and broken clods were ground on wooden plank with wooden roller and passed through a 2 mm sieve. A part of moist soil (prior to drying and grinding) was kept in refrigerator for the analysis of soil biological properties. The rest part of the soil samples were then stored in polythene bags. The homogenized soil samples were analyzed for selected physico-chemical and biological properties.

### Physico-chemical and biological properties measurement

The analysis of samples was done on the basis of standard methods. The pH and EC of soils were measured in 1: 2.5 (Soil: Water) suspension with the help of glass electrode digital pH meter. Organic carbon of the soils was estimated by chromic acid wet digestion method given by Walkley and Black 1934. Available Nitrogen content in soil was determined using Kjeltec Semi-Auto Nitrogen Analyzer by alkaline Potassium permanganate method. Available phosphorus content of soil was determined by using 0.5M $NaHCO_3$. Available potassium content of soil was determined by Flame Photometer neutral *N* ammonium acetate method described by Hanway and Heidal, 1952. Urease and phosphatase activity in soil was measured by adopting the method proposed by Tabatabai, 1982). Dehydrogenase activity was measured by the method proposed by Casida *et al*. (1964). Fumigation-extraction method was applied for microbial biomass carbon determination (Vance *et al*., 1987). Soil respiration was estimated by the method of Anderson, (1982). Total bacteria, fungi and actinomycetes were estimated by the serial dilution and plating techniques as described by Rolf and Bakken (1987). The following media were used for plating. Thornton's Medium for Total Bacteria counts, Kenknight and Munaier's medium for Actinomycetes counts (Subba Rao, 1977), Martins Rose – Bengal – Streptomycin - Agar medium for fungal counts (Martin, 1950)

### Statistical Analysis

Data obtained from all the observations were statistically analyzed. The correlation between different soil parameters was statistically calculated. All the soil samples were grouped in different categories on the basis of organic carbon content. The soils of Varanasi district were categorised into five groups *viz.* $G_1$ (1.1-2.0 g OC $kg^{-1}$soil), $G_2$ (2.1-3.0 g OC $kg^{-1}$soil), $G_3$ (3.1-4.0 g OC $kg^{-1}$soil), $G_4$ (4.1-5.0 g OC $kg^{-1}$soil) and $G_5$ (6.1-7.0 g

OC $kg^{-1}$soil). The correlation between different groups of soil was statistically calculated.

## RESULTS AND DISCUSSION

The soils of Varanasi district have been categorized in five groups viz. $G_1$ (< 2.0 g OC $kg^{-1}$ soil), $G_2$ (2.1-3.0 g OC $kg^{-1}$soil), $G_3$ (3.1-4.0 g OC $kg^{-1}$ soil), $G_4$ (4.1-5.0 g OC $kg^{-1}$soil) and $G_5$ (>0.50 g OC $kg^{-1}$soil). Out of 24 samples, 5 were belonging to $G_1$, 13 to $G_2$, 3 to $G_3$, 1 to $G_4$ and 2 samples were grouped in $G_5$.

The Physico-chemical properties of the soils of Varanasi (Table 2.1 & 2.2) showed that pH was varying from 7.1 to 9.2 i.e. from neutral to strong alkaline with mean value of 7.6. Electrical conductivity of the soils in cereal, legume, sugarcane and vegetables cultivated lands in Varanasi districts (Table 2.1 & 2.1) varied from 0.169 to 0.714 $dSm^{-1}$ along with mean value of 0.325 $dSm^{-1}$.

The mean of SOC (Table 2.1) in Varanasi district was 3.0 g $kg^{-1}$ with range of 1.1 to 6.8 g $kg^{-1}$, Thus organic matter content was mostly in low category except few. The mean SOC in different soil groups of Varanasi (Table 2.2) varied from 1.1-1.8 g $kg^{-1}$ for $G_1$ with mean value of 1.46 g $kg^{-1}$; 2.30-3.0 g $kg^{-1}$ for $G_2$ with mean value of 2.70 g $kg^{-1}$; 3.3-3.9 g $kg^{-1}$ for $G_3$ with mean value of 3.67 g $kg^{-1}$; 4.50 g $kg^{-1}$ mean for $G_4$ and 6.3-6.8 g $kg^{-1}$ for $G_5$ with mean value of 6.55 g $kg^{-1}$. In Varanasi district 22 samples (about 92%), were found in low category (less than 5.0 g $kg^{-1}$ OC content). Only 2 samples had shown medium status of SOC (5.0-7.5 g $kg^{-1}$ OC content).

Plant available nitrogen content in Varanasi district has been varied from 163.0 to 301.0 kg $ha^{-1}$ with an average of 211.25 kg $ha^{-1}$(Table 2.1). The mean nitrogen content in different soil groups of district Varanasi were 190.8, 208.5, 251.0, 251.0 and 200.5 kg $ha^{-1}$ for $G_1$, $G_2$, $G_3$, $G_4$ and $G_5$, respectively (Table 2.2).

Plant available phosphorous contents in cultivated soils varied from 14.5 to 74.1 kg $ha^{-1}$ and 14.4 to 51.1 kg $ha^{-1}$ with mean value of 30.28 kg $ha^{-1}$ (Table 2.1). The mean Phosphorous content in

**Table 1.** Locations of Soil Samples of Varanasi District

| Sample no. | Global Position | Cropping system | FYM Used |
|---|---|---|---|
| VN-1 | N25$^0$ 13.597' E082$^0$ 54.651' | Vegetable | YES |
| VN-2 | N25$^0$ 13.489' E082$^0$ 55.101' | Chilli-Wheat | YES |
| VN-3 | N25$^0$ 13.173' E082$^0$ 54.771' | Rice-Wheat | YES |
| VN-4 | N25$^0$ 13.407' E082$^0$ 55.006' | Pea- Wheat-Moong | YES |
| VN-5 | N25$^0$ 13.610' E082$^0$ 54.640' | Rice-Wheat | YES |
| VN-6 | N25$^0$ 13.603' E082$^0$ 54.653' | Rice-Wheat | YES |
| VN-7 | N25$^0$ 13.301' E082$^0$ 51.910' | Urd-Wheat-Vegetable | YES |
| VN-8 | N25$^0$ 13.433' E082$^0$ 57.927' | Til-Wheat-Vegetable | YES |
| VN-9 | N25$^0$ 13.376' E082$^0$ 51.883' | Rice-Wheat | YES |
| VN-10 | N25$^0$ 13.345' E082$^0$ 51.910' | Rice-Wheat | NO |
| VN-11 | N25$^0$ 13.324' E082$^0$ 51.908' | Rice-Wheat | YES |
| VN-12 | N25$^0$ 13.310' E082$^0$ 51.896' | Rice-Wheat | YES |
| VN-13 | N25$^0$ 13.176' E082$^0$ 51.291' | Rice-Wheat | YES |
| VN-14 | N25$^0$ 13.177' E082$^0$ 51.292' | Rice-Wheat | YES |
| VN-15 | N25$^0$ 13.178' E082$^0$ 51.290' | Rice-Wheat | YES |
| VN-16 | N25$^0$ 13.180' E082$^0$ 51.291' | Sugarcane | YES |
| VN-17 | N25$^0$ 13.182' E082$^0$ 51.293' | Rice-Wheat | YES |
| VN-18 | N25$^0$ 13.182' E082$^0$ 51.293' | Rice-Wheat | YES |
| VN-19 | N25$^0$ 12.678' E082$^0$ 52.693' | Rice-Wheat | YES |
| VN-20 | N25$^0$ 12.656' E082$^0$ 52.638' | Til-Wheat-Maize | YES |
| VN-21 | N25$^0$ 12.635' E082$^0$ 52.684' | Vegetable | YES |
| VN-22 | N25$^0$ 12.648' E082$^0$ 52.634' | Til-Wheat-Maize | NO |
| VN-23 | N25$^0$ 12.632' E082$^0$ 52.657' | Rice-Wheat | YES |
| VN-24 | N25$^0$ 12.678' E082$^0$ 52.693' | Til-Wheat-Maize | YES |

different designed groups was 37.6, 27.3, 31.7, 21.7 and 33.5 kg $ha^{-1}$ (Table 2.2) for $G_1$, $G_2$, $G_3$, $G_4$ and $G_5$, respectively. Result showed that available potassium content of analysed samples of Varanasi district (Table 2.1& 2.2) varied between 65.70 to 1358 kg $ha^{-1}$ with mean value of 208.29 kg $ha^{-1}$.

**Table 2.1.** Physico-chemical properties and available N, P, K and OC status of the soils of Varanasi district

| Group | Sample No. | pH | EC ($dSm^{-1}$) | OC (g $kg^{-1}$ soil) | Available Nutrients (Kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | | | | N | P | K |
| $G_1$ | VN-23 | 7.9 | 0.356 | 1.1 | 176 | 37.2 | 104.9 |
| | VN-17 | 7.7 | 0.325 | 1.4 | 188 | 74.1 | 192.6 |
| | VN-5 | 7.2 | 0.169 | 1.5 | 176 | 24.1 | 93.5 |
| | VN-8 | 7.6 | 0.374 | 1.5 | 188 | 27.5 | 94.8 |
| | VN-9 | 7.6 | 0.226 | 1.8 | 226 | 25.3 | 331.6 |
| $G_2$ | VN-14 | 7.9 | 0.357 | 2.3 | 176 | 26.7 | 100.4 |
| | VN-21 | 7.3 | 0.255 | 2.3 | 176 | 49.1 | 129.6 |
| | VN-12 | 7.1 | 0.269 | 2.3 | 201 | 22.9 | 146.3 |
| | VN-3 | 7.5 | 0.186 | 2.6 | 276 | 25.3 | 114.3 |
| | VN-13 | 7.3 | 0.246 | 2.6 | 188 | 22.5 | 91.3 |
| | VN-22 | 9.2 | 0.714 | 2.6 | 163 | 14.7 | 278.6 |
| | VN-6 | 7.5 | 0.253 | 2.7 | 226 | 22.9 | 90.8 |
| | VN-1 | 7.5 | 0.327 | 2.9 | 201 | 16.7 | 79.4 |
| | VN-2 | 7.4 | 0.207 | 2.9 | 251 | 14.5 | 65.7 |
| | VN-7 | 7.4 | 0.235 | 2.9 | 163 | 24 | 93.3 |
| | VN-16 | 7.9 | 0.445 | 3.0 | 226 | 27.9 | 108.5 |
| | VN-19 | 7.3 | 0.324 | 3.0 | 238 | 62.1 | 171.47 |
| | VN-24 | 7.8 | 0.244 | 3.0 | 226 | 25.3 | 133 |
| $G_3$ | VN-18 | 7.6 | 0.263 | 3.3 | 163 | 14.7 | 89.6 |
| | VN-11 | 7.4 | 0.226 | 3.8 | 301 | 21.7 | 134.9 |
| | VN-15 | 8.1 | 0.678 | 3.9 | 289 | 58.8 | 1358 |
| $G_4$ | VN-4 | 7.4 | 0.29 | 4.5 | 251 | 21.7 | 91.6 |
| $G_5$ | VN-10 | 7.4 | 0.324 | 6.3 | 213 | 28.7 | 206.5 |
| | VN-20 | 7.5 | 0.499 | 6.8 | 188 | 38.3 | 698.3 |
| Range | | 7.1-9.2 | 0.169-0.714 | 1.1-6.8 | 163-301 | 14.5-74.1 | 65.7-1385 |
| Mean | | 7.6 | 0.325 | 3.0 | 211.25 | 30.28 | 208.29 |
| + SD | | 0.42 | 0.14 | 1.37 | 40.31 | 15.64 | 277.98 |
| CV % | | 5.52 | 42.67 | 46.36 | 19.08 | 51.67 | 133.46 |

**Table 2.2.** Mean values of physico-chemical properties and available N, P, K and OC status in different soil groups of Varanasi district

| Group | pH | EC ($dSm^{-1}$) | OC (g $kg^{-1}$ soil) | Available Nutrients (Kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|
| | | | | N | P | K |
| $G_1$ | 7.6 (7.2-7.9) | 0.29 (0.169-0.374) | 1.46 (1.1-1.8) | 190.8 (176-226) | 37.6 (24.1-74.1) | 163.5 (93.5-331.6) |
| $G_2$ | 7.6 (7.1-9.2) | 0.312 (0.186-0.714) | 2.70 (2.3-3.0) | 208.5 (163-276) | 27.3 (14.5-62.1) | 123.3 (65.7-278.6) |
| $G_3$ | 7.7 (7.4-8.1) | 0.389 (0.226-0.678) | 3.67 (3.3-3.9) | 251.0 (163-301) | 31.7 (14.7-58.8) | 527.5 (89.6-1358) |
| $G_4$ | 7.4 | 0.29 | 4.50 | 251.0 | 21.7 | 91.6 |
| $G_5$ | 7.45 (7.4-7.5) | 0.411 (0.324-0.499) | 6.55 (6.3-6.8) | 200.5 (188-213) | 33.5 (28.7-38.3) | 452.4 (206.5-698.3) |

**Table 3.1.** Enzymatic activities of the soils of Varanasi district

| Group | Sample no. | Dehydrogenase (µg TPF $g^{-1}$ soil $day^{-1}$) | Urease (µg UH $g^{-1}$ soil $h^{-1}$) | Phosphatase (µg PNP $g^{-1}$soil $h^{-1}$) | |
|---|---|---|---|---|---|
| | | | | Alkaline | Acid |
| $G_1$ | VN-23 | 24.33 | 128.6 | 73.6 | 57.3 |
| | VN-17 | 25 | 147.7 | 68.7 | 60.3 |
| | VN-5 | 27.66 | 149.7 | 85.6 | 68.3 |
| | VN-8 | 27 | 152.3 | 82.3 | 65.6 |
| | VN-9 | 29.66 | 171.6 | 96.3 | 71.3 |
| $G_2$ | VN-14 | 33 | 191.3 | 124.6 | 82.6 |
| | VN-21 | 33 | 188.7 | 118.3 | 78.3 |
| | VN-12 | 32.66 | 197.6 | 129.3 | 83.6 |
| | VN-3 | 35.33 | 222.6 | 141.6 | 96.3 |
| | VN-13 | 35 | 211.6 | 146.6 | 92.3 |
| | VN-22 | 36.33 | 208.3 | 149.3 | 89.6 |
| | VN-6 | 38.25 | 280.3 | 167.67 | 97.6 |
| | VN-1 | 41.25 | 241.7 | 168.6 | 102.6 |
| | VN-2 | 41.67 | 251.3 | 175.3 | 108.2 |
| | VN-7 | 42.33 | 238.6 | 162.6 | 100.6 |
| | VN-16 | 43.5 | 253.6 | 168.6 | 103.5 |
| | VN-19 | 44.33 | 280.3 | 130.3 | 102.6 |
| | VN-24 | 44.25 | 257.3 | 173.3 | 105.5 |
| $G_3$ | VN-18 | 48.66 | 261.6 | 184.8 | 110.3 |
| | VN-11 | 52.33 | 286.7 | 181.76 | 113.5 |
| | VN-15 | 55.67 | 291.6 | 138.6 | 115.7 |
| $G_4$ | VN-4 | 61.25 | 314.7 | 193.6 | 122.67 |
| $G_5$ | VN-10 | 67.5 | 326.3 | 211.7 | 142.6 |
| | VN-20 | 70.33 | 342.3 | 210.3 | 162.3 |
| Range | | 24.33-70.33 | 128.60-342.30 | 68.70-211.70 | 57.30-162.30 |
| Mean | | 41.26 | 233.18 | 145.14 | 97.22 |
| + SD | | 12.74 | 59.68 | 41.75 | 24.95 |
| CV % | | 30.88 | 25.59 | 28.76 | 25.67 |

**Table 3.2.** Mean values of enzymatic activities in different soil groups of Varanasi district.

| Group | Dehydrogenase (µg TPF $g^{-1}$ soil $day^{-1}$) | Urease (µg UH $g^{-1}$ soil $h^{-1}$) | Phosphatase (µg PNP $g^{-1}$soil $h^{-1}$) | |
|---|---|---|---|---|
| | | | Alkaline | Acid |
| $G_1$ | 26.73 (24.33-29.66) | 149.98 (128.6-171.6) | 81.3 (68.7-96.3) | 64.56 (57.3-71.3) |
| $G_2$ | 38.53 (32.66-44.33) | 232.55 (188.7-280.3) | 150.47 (118.3-175.3) | 95.64 (78.3-108.2) |
| $G_3$ | 52.22 (48.66-55.67) | 279.97 (261.6-291.6) | 168.39 (138.6-184.8) | 113.17 (110.3-115.7) |
| $G_4$ | 61.25 | 314.7 | 193.6 | 122.67 |
| $G_5$ | 68.92 (67.5-70.33) | 334.3 (326.3-342.3) | 211 (210.3-211.7) | 152.45 (142.6-162.3) |
| R | 0.967 | 0.932 | 0.927 | 0.988 |
| t cal | 6.61 | 4.46 | 4.28 | 11.23 |
| t tab (p= 0.05) | 3.18 | 3.18 | 3.18 | 3.18 |
| S/NS | S | S | S | S |

**Table 4.1.** Soil microbial biomass carbon (SMBC) and soil respiration values of the soils of Varanasi district

| Group | Sample no. | Soil Microbial Biomass Carbon (mg C $kg^{-1}$ soil) | Soil Respiration (mg $CO_2$-C $g^{-1}$ soil $day^{-1}$) |
|---|---|---|---|
| $G_1$ | VN-23 | 90.6 | 0.1992 |
| | VN-17 | 110.5 | 0.2012 |
| | VN-5 | 121.3 | 0.2345 |
| | VN-8 | 116.6 | 0.2378 |
| | VN-9 | 132.6 | 0.2587 |
| $G_2$ | VN-14 | 167.6 | 0.2965 |
| | VN-21 | 161.3 | 0.2934 |
| | VN-12 | 165.3 | 0.2974 |
| | VN-3 | 189.6 | 0.3216 |
| | VN-13 | 192.3 | 0.3228 |
| | VN-22 | 195.3 | 0.3296 |
| | VN-6 | 196.5 | 0.3389 |
| | VN-1 | 201.5 | 0.3621 |
| | VN-2 | 202.67 | 0.3576 |
| | VN-7 | 204.5 | 0.3624 |
| | VN-16 | 208.33 | 0.3772 |
| | VN-19 | 208 | 0.3746 |
| | VN-24 | 204 | 0.3785 |
| $G_3$ | VN-18 | 221.67 | 0.4134 |
| | VN-11 | 240.6 | 0.4467 |
| | VN-15 | 246.67 | 0.4587 |
| $G_4$ | VN-4 | 280.3 | 0.5068 |
| $G_5$ | VN-10 | 310 | 0.5136 |
| | VN-20 | 321.3 | 0.5421 |
| Range | | 90.60-321.30 | 0.1992-0.5421 |
| Mean | | 195.38 | 0.3511 |
| + SD | | 58.55 | 0.09 |
| CV % | | 29.97 | 26.96 |

**Table 4.2.** Mean values of Soil microbial biomass carbon (SMBC) and soil respiration in different soil groups of Varanasi district

| Group | Soil Microbial Biomass Carbon (mg C $kg^{-1}$ soil) | Soil Respiration (mg $CO_2$-C $g^{-1}$ soil $day^{-1}$) |
|---|---|---|
| $G_1$ | 114.32 | 0.2263 |
| | (90.6-132.6) | (0.1992-0.2587) |
| $G_2$ | 192.07 | 0.3394 |
| | (161.3-208.33) | (0.2934-0.3785) |
| $G_3$ | 236.31 | 0.4396 |
| | (221.67-246.67) | (0.4134-0.4587) |
| $G_4$ | 280.3 | 0.5068 |
| $G_5$ | 315.65 | 0.5279 |
| | (310-321.3) | (0.5136-0.5421) |
| r | 0.964 | 0.930 |
| t cal | 6.30 | 4.37 |
| t tab (p=0.05) | 3.18 | 3.18 |
| S/NS | S | S |

Further it showed that 54% soils among the analysed soil samples in Varanasi districts were in low range, 33% soils were in medium range and only 13% were in high range.

The dehydrogenase activity of Varanasi soil ranged from 24.33 µg TPF $g^{-1}$ soil $day^{-1}$ to 70.33 µg TPF $g^{-1}$ soil $day^{-1}$. The mean dehydrogenase enzyme activity for $G_1$, $G_2$, $G_3$, $G_4$ and $G_5$ soil (Table 3.2) was 26.73, 38.53, 52.22, 61.25, and 68.92 µg TPF $g^{-1}$ soil $day^{-1}$, respectively. Data revealed that soil $G_5$ had higher (68.92µg TPF $g^{-1}$ soil $day^{-1}$) dehydrogenase activity than all other soil samples because of higher organic matter content of soils which was at par to some of other samples. Liu *et al*. (2010) also observed an increase in dehydrogenase activity by application of FYM over control.

Urease activity in the soil of Varanasi district (Table 3.1&3.2) showed variation from 128.60-342.30 µg urea hydrolysed $g^{-1}$ soil $h^{-1}$ with mean value of 233.18 µg urea hydrolysed $g^{-1}$ soil $h^{-1}$--. The lowest urease enzyme activity (Table3.1. & 3.2) with mean value of 149.98 µg urea hydrolysed $g^{-1}$ soil $h^{-1}$ was associated with $G_1$ and highest in $G_5$ soil with mean value of 334.3 µg urea hydrolysed $g^{-1}$ soil $h^{-1}$.The urese enzyme activity was in the sequence of $G_5 > G_4 > G_3 > G_2 > G_1$, with similar trends to the content of organic carbon. Chhonkar and Tarafdar (1981) found that the activities of enzymes were significantly and positively correlated with organic carbon, fungal, bacterial and actinomycetes population in the soil.

Alkaline phosphatase activity of district Varanasi was ranging from 68.70 to 211.70 µg PNP $g^{-1}$ soil $h^{-1}$. In mean table of soil group the lowest alkaline phosphatise activity was observed in $G_1$ soil (81.3 µg PNP $g^{-1}$ soil $h^{-1}$) and highest was observed in $G_5$ soil (211.0 µg PNP $g^{-1}$ soil $h^{-1}$). The values of alkaline phosphatase activity were significantly correlated with organic matter with r value of 0.972. Mandal *et al.* (2007) observed significantly higher activities of alkaline phosphatase in NPK+FYM amended soils over 100% NPK or control plots. Lower acidic phosphatase enzyme activity was observed in soils of Varanasi districts (Table 3.1 and 3.2). This enzyme was consistent with the higher pH of soils being unfavourable for acidic phosphatase activity. Earlier, researchers have also reported that phosphatase activity was strongly influenced by soil pH (Eivazi and Tabatabai, 1977; Dick, 1994). A positive correlation was reported between acidic phosphatase and SOC content. Since, soil enzyme activities were generally related to soil organic matter content (Frankenberger and Dick, 1983) build up of organic matter was the main cause of enhanced phosphatase enzyme activities. The microbial biomass carbon in Varanasi (Table 4.1 & 4.2) soil registered a range between 90.60 to 321.30 mg C $kg^{-1}$soil with an average value of 195.38 mg C $kg^{-1}$ soil. In group study higher (315.65 mg C $kg^{-1}$ soil) microbial biomass carbon of district Varanasi was recorded in $G_5$ soils which were 176.1% more than $G_1$ soils. The range of microbial biomass carbon was consistent with several other workers (Manna *et al.,* 2005, Kautz *et al.,* 2004, Mandal *et al.,* 2007). The values of SMBC were positively correlated with SOC with r value of 0.964 and the correlation was highly significant.

Soil respiration in the Varanasi district (Table 4.1&4.2) lies between the ranges of 0.1992 to 0.5421 mg $CO_2$-C $g^{-1}$ soil $day^{-1}$ with an average of 0.3511 mg $CO_2$-C $g^{-1}$ soil $day^{-1}$. Soil respiration observation was lowest in $G_1$ (0.2263 mg $CO_2$-C $g^{-1}$ soil $day^{-1}$) and highest in $G_5$ (0.5279 mg $CO_2$-C $g^{-1}$ soil $day^{-1}$).The values of soil respiration were positively correlated with organic matter content of soil with r value of 0.930 for district Varanasi. There was a statistically significant correlation was established between the two parameter, soil respiration and soil organic matter content. Due to higher microbial population in $G_5$ soil group of Varanasi district the value of $CO_2$ evolution was higher over the other soil groups. Gilani and Bahmanyar (2008) reported that the SOC was significantly correlated with soil microbial respiration.

Perusal of data revealed that the bacterial population of Varanasi district (Table 5.1 & 5.2) varied between 14.20 to 42.70 x $10^6$ CFU $g^{-1}$ with mean value of 23.46 x $10^6$ CFU $g^{-1}$. The highest 42.19 x $10^6$ CFU $g^{-1}$ soil in $G_5$ soil samples of Varanasi district which was significantly higher than other soil samples of Varanasi districts. Bacterial population of were significantly correlated with soil organic carbon content. Venkateswarlu and Srinivasarao (2004) showed that both the microbial population and diversity index increased in presence of FYM than fertilization and control.

The fungal and actinomycetes population

in the soils of Varanasi districts (Table 5.1 & 5.2) followed the same trend of bacterial population, but the values were lower. The values of fungal population varied from 6.7 to 32.70 x $10^4$ CFU $g^{-1}$

**Table 5.1.** Microbial Population of the soils of Varanasi district

| Group | Sample no. | Bacteria (CFU × $10^6$ $g^{-1}$ soil) | Fungi (CFU × $10^4$ $g^{-1}$ soil) | Actinomycetes (CFU × $10^5$ $g^{-1}$ soil) |
|---|---|---|---|---|
| $G_1$ | VN-23 | 14.2 | 6.7 | 10 |
| | VN-17 | 14.5 | 7 | 9.3 |
| | VN-5 | 15 | 9 | 12.3 |
| | VN-8 | 15.7 | 8 | 12.7 |
| | VN-9 | 16 | 8.7 | 13.3 |
| $G_2$ | VN-14 | 19.7 | 10 | 18.3 |
| | VN-21 | 17.7 | 10.3 | 13.7 |
| | VN-12 | 17 | 16 | 13 |
| | VN-3 | 20.3 | 12 | 15.7 |
| | VN-13 | 18.6 | 12 | 15 |
| | VN-22 | 38 | 7.5 | 30.67 |
| | VN-6 | 21 | 13 | 16 |
| | VN-1 | 21.6 | 15 | 17.3 |
| | VN-2 | 20.7 | 14.3 | 16.3 |
| | VN-7 | 21.33 | 15 | 16 |
| | VN-16 | 24.7 | 16.7 | 21.7 |
| | VN-19 | 23 | 17 | 18 |
| | VN-24 | 24 | 17.3 | 20 |
| $G_3$ | VN-18 | 25 | 19.4 | 20.7 |
| | VN-11 | 26 | 21.3 | 23 |
| | VN-15 | 26.67 | 18.33 | 25.5 |
| $G_4$ | VN-4 | 38 | 26.7 | 26 |
| $G_5$ | VN-10 | 41.67 | 30.3 | 29.7 |
| | VN-20 | 42.7 | 32.7 | 31.3 |
| Range | | 14.20-42.70 | 6.70-32.70 | 9.30-31.30 |
| Mean | | 23.46 | 15.18 | 18.56 |
| + SD | | 8.45 | 7.07 | 6.35 |
| CV % | | 36.03 | 46.60 | 34.23 |

**Table 5.2.** Mean values of Microbial Population in different soil groups of Varanasi district

| Group | Bacteria (CFU × $10^6$ $g^{-1}$ soil) | Fungi (CFU × $10^4$ $g^{-1}$ soil) | Actinomycetes (CFU × $10^5$ $g^{-1}$ soil) |
|---|---|---|---|
| $G_1$ | 15.08 | 7.88 | 11.52 |
| | (14.2-16) | (6.7-9) | (9.3-13.3) |
| $G_2$ | 22.13 | 13.55 | 17.82 |
| | (17-38) | (7.5-17.3) | (13-30.67) |
| $G_3$ | 25.89 | 19.68 | 23.07 |
| | (25-26.67) | (18.33-21.3) | (20.7-25.5) |
| $G_4$ | 38 | 26.7 | 26 |
| $G_5$ | 42.19 | 31.5 | 30.5 |
| | (41.67-42.7) | (30.3-32.7) | (29.7-31.3) |
| R | 0.962 | 0.978 | 0.976 |
| t cal | 6.14 | 8.03 | 7.69 |
| t tab (p=0.05) | 3.18 | 3.18 | 3.18 |
| S/NS | S | S | S |

**Table 6.** Values of the coefficient of correlation (r) between different variables observed in soil samples of district Varanasi

| | Var. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EC | 1 | — | | | | | | | | | | | | | | |
| pH | 2 | 0.78* | — | | | | | | | | | | | | | |
| Organic carbon | 3 | 0.25 | -0.09 | — | | | | | | | | | | | | |
| Nitrogen | 4 | -0.05 | -0.14 | 0.26 | — | | | | | | | | | | | |
| Phosphorous | 5 | 0.25 | -0.02 | -0.05 | 0.08 | — | | | | | | | | | | |
| Potassium | 6 | 0.67* | 0.30 | 0.38 | 0.32 | 0.44* | — | | | | | | | | | |
| Debydrogenase | 7 | 0.25 | -0.07 | 0.97* | 0.36 | -0.05 | 0.41* | — | | | | | | | | |
| SMBC | 8 | 0.24 | -0.05 | 0.96* | 0.35 | -0.14 | 0.34 | 0.98* | — | | | | | | | |
| Urease | 9 | 0.17 | -0.11 | 0.90* | 0.47* | -0.09 | 0.32 | 0.94* | 0.96* | — | | | | | | |
| Alkl. phosphatase | 10 | 0.06 | -0.06 | 0.84* | 0.28 | 0.42* | 0.07 | 0.86* | 0.92* | 0.91* | — | | | | | |
| Acid phosphatase | 11 | 0.21 | -0.09 | 0.97* | 0.34 | -0.14 | 0.35 | 0.97* | 0.98* | 0.96* | 0.92* | — | | | | |
| Soil respiration | 12 | 0.24 | -0.06 | 0.94* | 0.40 | -0.13 | 0.38 | 0.99* | 0.99* | 0.96* | 0.90* | 0.97* | — | | | |
| Bacteria | 13 | 0.48* | 0.28 | 0.88* | 0.14 | -0.14 | 0.32 | 0.87* | 0.88* | 0.79* | 0.77* | 0.84* | 0.85* | — | | |
| Fungi | 14 | 0.09 | -0.27 | 0.95* | 0.32 | -0.07 | 0.28 | 0.96* | 0.93* | 0.90* | 0.83* | 0.94* | 0.94* | 0.79* | — | |
| Actinomycetes | 15 | 0.58* | 0.40 | 0.84* | 0.21 | -0.17 | 0.43* | 0.85* | 0.87* | 0.79* | 0.76* | 0.83* | 0.86* | 0.96* | 0.74* | — |

* Significant at 5% level

soil. The highest fungal population was observed in $G_5$ (31.5 x $10^4$ CFU $g^{-1}$ soil) while, lowest was in $G_1$ with mean value of 7.88 x $10^4$ CFU $g^{-1}$ soil. Fungal population of district Varanasi was significantly correlated with soil organic carbon content having r value of 0.978 for Varanasi district. Fungi population was negatively correlated with soil pH, because fungal population prefers acidic range of soil pH, so more population of fungi were associated with low pH.

The actinomycetes population in soils of district Varanasi was in the range of 9.30 to 31.30 x $10^5$ CFU $g^{-1}$ soil with mean value of 18.56 x $10^5$ CFU $g^{-1}$ soil. In group study of soil samples, population of actinomycetes were ranging from 11.52 x $10^5$ CFU $g^{-1}$ soil in $G_1$ to maximum 30.5 x $10^5$ CFU $g^{-1}$ soil in $G_5$ soil. The actinomycetes population varied from 9.3 to 26.7 x $10^5$ CFU $g^{-1}$ soil with mean value of 19.95 x $10^5$ CFU $g^{-1}$ soil. Organic carbon showed significant positive correlation with fungal and bacterial populations. The application of organic fertilizers increased the organic carbon content of the soil and thereby increasing the microbial counts.

It was, therefore found that content of organic carbon in the soils was main factor to influence soil enzyme activity, SMBC, soil respiration and population of bacteria, fungi and actinomycetes with positive correlation with each other. The correlation coefficient (r) between different soil properties were presented in Table 6.

## CONCLUSIONS

Most of the soil samples were neutral in reaction and belonging to the low fertility status of organic carbon and available nitrogen. All the biological properties were highest in $G_5$ group of soil. Higher mean value of all the enzymes were reported in $G_5$ soil group over $G_1$ soil group because of higher value of organic carbon in $G_5$ group. All these enzyme activities were increasing with increase in SOC and microbial population. Bacteria, Fungi and Actinomycetes population was increased significantly with increased in soil enzyme activities.Due to increase in the microbial population, there was significant and positive correlation seen in the $CO_2$ evolution and microbial population. SMBC was also highest where SOC and microbial population registered a highest value.SMBC was reported highest where microbial population attain a peak value this is because of MBC is a part of carbon which comes out from the microbial body.

In view of the summarized experimental findings, it may be concluded that the soil organic carbon content was the most dominating factor which alone influence most of the soil biological processes and activities. Most of the analysed soil samples were poor in organic matter content as well as poor in soil biological health status. Status of SOC in soil was alarming from soil health point of view so that there is an urgent need to improve SOC status by the application of organic manures along with different component of INM.

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