*International Journal of Plant & Soil Science*
*11(2): 1-14, 2016; Article no.IJPSS.26033*
*ISSN: 2320-7035*

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# Soil Fertility Status in and Around the Tea-Garden Belt of Belwa, Kishanganj District, Bihar, India

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author AK designed the study, wrote the protocol, wrote the first draft of the manuscript, analyses of the study performed the spectroscopy analysis and statistical analysis. Author Seema managed the literature searches, experimental process and identified the species of plant. Both authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/IJPSS/2016/26033
*Editor(s):*
(1) Eliana L. Tassi, Institute of Ecosystem Studies, National Research Council (ISE-CNR), Italy.
*Reviewers:*
(1) Addam Kiari Saidou, National Institute of Agronomic Research of Niger (INRAN), Niger.
(2) W. B. Tomori, Federal University of Technology, Akure, Nigeria.
Complete Peer review History: http://sciencedomain.org/review-history/14585

***Original Research Article***

***Received 30th March 2016***
***Accepted 28th April 2016***
***Published 12th May 2016***

## ABSTRACT

Soil is one of the most significant ecological factors, on which plants depend for their nutrients, water and mineral supply. Pesticides, fertilizers and agrochemicals applied by tea growers are largely retained by the soil. They undergo degradation in soil through the processes of biodegradation, chemical degradation or photochemical reactions. Therefore, environmental health aspects of soil deserve serious attention in near future. The aim of the present research work is to monitor the status of the soil fertility in and around tea garden belt of Belwa, Kishanganj district, Bihar, India. Thirty soil samples were collected from top soil (1-15 cm) in and around (paddy field) of five selected tea gardens during 2014 - 2015. Soil samples were analyzed for pH, EC, OC (%), BD, macronutrients and micronutrients. Results revealed that, pH of soil varied from 4.4-5.7, which suggest that soil in the study areas was acidic. The total organic carbon ranged from 0.76-1.81(%) and available N, P and K content varied from 255.25 to 431.21; 9.32 to 31.32; 45.98 to 182.81 kg/ha respectively. Mn, Fe, Cu and Zn concentrations varied from 130.12 to 412.71; 91.23 to 278.2; 14.99 to 29.67; 22.12 to 46.23 and mg/kg respectively. Correlation study revealed that

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macronutrient and micronutrient showed positive correlation with pH and organic carbon (%). Moreover tea growers and farmers of the study areas applied higher amount of N-based fertilizers then P and K based fertilizers causing a decrease in soil available P and exchangeable K. Therefore this research work will be helpful in reconciling of local and scientific knowledge among tea growers and farmers which may be the most important step to obtain satisfactory level of crop production and maintenance of soil fertility and productivity.

*Keywords: Top soil; tea garden; paddy field; physiochemical parameters; macronutrients; micronutrients.*

## 1. INTRODUCTION

Soil plays a very important role as it produces food for human as well as for animal consumption. But, due to human activities, soil is the receptor of many pollutants including synthetic fertilizers, pesticides and particulate matter for power plant, smoke stacks etc. Deterioration of soil and water quality due to geological conditions and injudicious use of chemical fertilizers and pesticides in tea gardens is now a serious issue in tea industries of India [1-3].

For healthy growth of plants, it is necessary that all the needs of plants be met with according to their requirements. A shortage of nutrients can cause serious restrictions to crop growth, thereby fertility of the soil [4,5]. Soil macronutrient (N, P, and K) and micronutrients (Mn, Fe, Cu, and Zn) are essential for the tea plants but excessive use of chemical fertilizers, pesticides and weedicides by the tea growers and farmers for high yield of tea can increase the potential hazardous elements in the field, which reduces soil fertility and is a source of contamination of surface and groundwater [6,7].

Now a day's soil health is an alarming challenge to ensure profitable productivity. Due to extensive monoculture of tea, changes such as increased acidity, nutrient depletion, loss of organic matter has resulted in tea soils [8]. Soil compaction, intensive leaching of bases and increased acidity, low nutrient holding capacity and reduced biodiversity of the tea soils are some of the consequences. Several researchers reported [9,10] that over a 40-year cropping of tea, up to 252 tons/ha of organic matter were to be lost from a 90 cm soil profile along with depletion of considerable amounts of nutrients. The unabated depletion of organic matter and nutrients lead to decline of productivity and fertility of tea soils. To maintain a high productivity of tea, the soil needs regular supplementation with fertilizers. An average crop of 2000 kg made tea/ha will remove around 100 kg nitrogen, 20 kg phosphate and 40 kg potash per ha per year from soil in addition to nutrients locked up in the bush frame [11]. Urea, rock phosphate, single superphosphate and muriate of potash are extensively used in tea fields. Borpujari and Dey [12] reported that among the micronutrients, foliar sprays of zinc is used widely as a regular practice in tea plantations either alone or mixed with urea. Soil nutrients play important role in tea productivity. There is a tendency in some tea growers to use fertilizers at high rates or to emphasize only on nitrogen while phosphate is used in alternate or every third year and skipping potash. Such imbalanced nutrition leads to decline of productivity. Application of fertilizer at high doses causes theanine toxicity in roots leading to damage of feeder roots, depletion of starch from the roots and even death of plants in extreme cases [13]. It will also effect considerable leaching and runoff loss leading to contamination of nearby water bodies and ground water. Therefore high dose of fertilizer can cause several problems such as acidification of the soil, effect on livestock, cattle and human; pest and weed problem, eutrophication, nonavaility of micronutrient and destruction of soil structure.

Pesticide is composite and consists of all chemicals that are used to kill or control pests. It covers a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others. G. M. Das reported that more than 1000 species of arthropod pests of different groups are used in tea plantation all over the world, among them about 300 species of insects are recorded in India and only about 167 species from North-East India, causing 11 to 55% annual loss of tea [14].

Herbicides are the largest used pesticides in tea plantations unlike other crops in the country. Their use began in the sixties [15] and soon became popular as chemical weed control which is cheaper than manual methods. Paraquat, 2, 4-D and glyphosate are extensively used herbicides in tea fields and oxyfluorfen, glufosinate ammonium, simazine and diuron are used in a limited scale. Afolabi et al. [16] was reported that more than 50% of applied chemical fertilizers are lost to leaching, while more than 90% of pesticides do not reach the target pests. Primental [17] reported that millions tons of pesticides are applied annually but less than 5% of these product reach the target organism and remaining deposited into the soil, air and water resources.

Tea (*Camellia sinensis* L.) is the most important cash crop in the highland of North East India. It is a popular beverage used all over the world and has great impact on the economy of many tea producing countries. Tea originated in China as a medicinal drink [18]. Tea is grown in 13 states among which Assam, West Bengal, Tamil Nadu and Kerala are the largest producers. Development of small tea gardens by the small tea growers in the rural areas is very important in a Kishanganj district in Bihar (India), for providing employment opportunities which increases the income level of the rural youth. Although small tea growers are benefitted more by growing use of chemical fertilizers and pesticides in the small tea gardens, it adversely affects soil, water, air and non-target vegetation. Due to lack of environmental awareness, inappropriate use of synthetic fertilizers and pesticides by the small tea growers, soil fertility status in and around the tea- gardens of Kishanganj, is likely to be gradually degrading. Necessary steps are yet to be taken to overcome the problems related to the use of chemical fertilizers and pesticides in the small tea gardens of Kishanganj district in Bihar, India.

So an attempt has been made in this paper to know the present status of soil fertility in and outside (paddy field) of tea garden of Belwa Panchayat of Kishanganj, and creating awareness to farmers and tea growers for judicious use of chemical fertilizers and pesticides which is necessary to avoid pollution of water sources and contamination of the soil.

## 2. MATERIALS AND METHODS

### 2.1 Field Description

Kishanganj is the only district in Bihar state (India), where tea plantation has developed and today, Bihar has been put on the tea map of the country. It is located in the north-east of the state of Bihar, at latitude of 25° 20’ to 26° 30’ north and longitude of 87° 7’ to 88° 19’ east (Fig. 1). The total area of it is 1,884 square km. and total irrigated area of 262.2 square km. West Bengal, Nepal and Bangladesh are at border line of it. The important rivers flowing through the district are Mahananda, Kankai, Mechi, Ratwa, Ramzan Suhdani (Ram Chandra), Donk and Kaul. The Mahananda River flows through the Indian states of West Bengal, Bihar, and Bangladesh. Right bank tributary Mechi forms part of Nepal's eastern boundary with West Bengal and the Kankai crosses out of Nepal. The Mahananda originates in the Himalayas: Mahaldiram Hill near Chimli, east of Kurseong in Darjeeling district at an elevation of 2,100 meters (96900 ft). The climate of the study area was humid with maximum temperature 40℃ in May-June and minimum of 5℃ in January. The average rainfall is 2250 mm of which 80% occurs during monsoon. The climatic condition of this district is suitable for tea cultivation.

The huge potential of tea plantation (Kishanganj, Pothia and Thakurganj blocks) in this district is because it is on the foothills of the Himalayas and in the vicinity of Darjeeling district of West Bengal. Hardly 10 Km from Kishanganj head quarter there are acres and acres lush tea garden in Belwa of Kishanganj block. Tea plantation has made quantum jump in Kishanganj district in the early part of 1990s. The development of tea plantation in this district is not to originate very large employment opportunities, but to invert the migration of workers from Bihar and increase the income level of the rural people. The Tea Board of India, foreseeing the tremendous potential, has declared five blocks of Pothia, Thakurganj, Kishanganj, Bahadurganj and Dighalbank non-traditional areas for growing tea under its new area development scheme. The lack of government support, production of tea processed from the leaves of Kishanganj has now touched 600 kg per hectare, compared to 300 kg in Darjeeling and 504 kg in north Assam. The plantations raised by the businessmen - mostly Muslim, Marwaris and Jains - on 2,500 acres of land recorded a production of 3,500 tons this year. By the turn of the century, the area under cultivation is expected to double to 5,000 acres with the production of tea trebling to over 10,000 tones. Today the green tea leaves grown in the district is in high demand and has thrown a challenge to the states of west Bengal and Assam which are traditional tea growing states of India.

## 2.2 Collection of Soil Samples

Thirty soil samples were collected from in (tea gardens) and outside (paddy fields) of five selected tea gardens of Belwa panchayat of Kishanganj district. Soil samples were taken from 1-15 cm depth from each area by adopting sample random technique by maintaining a distance about 45 meters between two samples. With help of spade or cutlass, contaminated surface soil materials was removed and digging V shaped holes, up to depth of 15 cm, a uniform of 2 cm thick slice of soil samples were collected in plastic buckets. Quartering technique was applied to reduce the size of the sample to required mass and air dried. The air dried samples were thoroughly mixed on a piece of clean cloth and the bigger pieces were broken using pestle and mortar [19]. Three samples from each location were collected two times at 30 days interval to determine the average value of the results, which were compared with chemical rating chart recommended by ICIR 2005.

## 2.3 Laboratory Methods

For determination of pH of soil samples, 20 g soil was mixed with 40 mL distilled water. The resulting suspension was then shaken for half an hour and then allowed to stand for one hour. The pH of the clear supernatant was finally measured by a digital pH meter at 25℃. The electrical conductance (EC) was measured by using digital conductivity meter. Fifteen grams of soil sample were mixed with 30 mL of distilled water and then suspension was filtered through Whatmann No.1 filter paper. The filtrate was then stirred intermittently and then allowed to stand for 30-40 minutes for complete dissolution of soluble salts. The soil water mixture was again allowed to stand so that soil settled down. Finally electrical conductance was recorded by inserting conductivity cell in it.

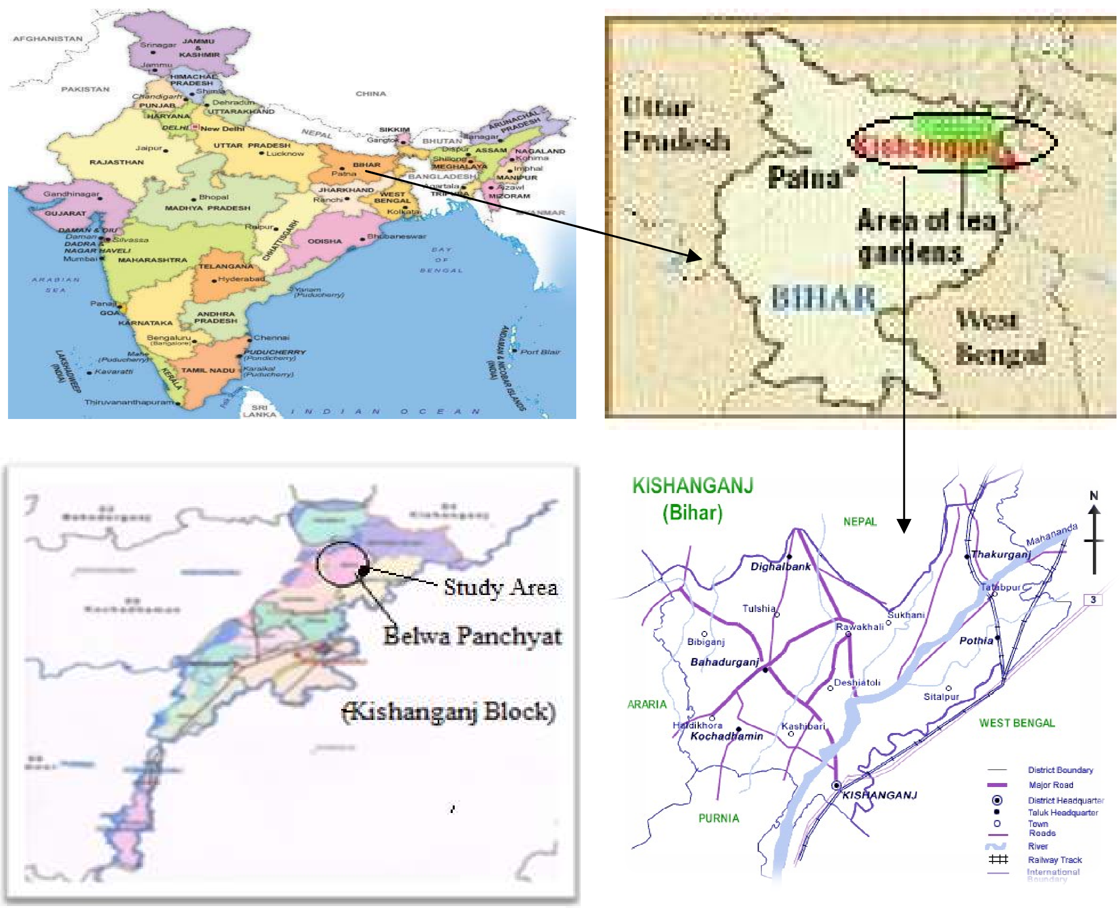


**Fig. 1. Location of study area**

Organic carbon ($C_{org}$) in the soil was measured by Walkey-Black method [20] modified by Jackson [21]. In this method 0.5 g soil sample was mixed with 0.2M $K_2Cr_2O_7$ solution and then diluted with $H_2SO_4$ (1:1). The mixture was allowed to stand for 30-40 minutes and then sodium fluoride solution was added to it. The above mixture was titrated with standard solution of ferrous ammonium sulfate in presence of diphenyl ammine as indicator and then organic carbon % was calculated using the equation given below:

$$\text{Organic C \%} = \frac{10(B-T)}{B}\, x\, 0.003x\, \frac{100}{Wt\ of\ Soil} x1.94$$

Where, B is the volume of ferrous ammonium sulfate required for Blank and T is the volume of ferrous ammonium sulfate required for Soil.

The available nitrogen in soil was a determination as ammonium and nitrate nitrogen by the literature described by Bremner and Mulveney [22] and modified by Tan [23]. In this method 10 g of the soil sample was mixed with 50 mL of 2M KCl solution. After shaking for one hour, the extract was filtered through Whatman No.2 filter paper and then the filtrate was used for the analysis of Ammonium and Nitrate N.

The potassium concentration in the soil samples was determined by flame photometrical method as described by Spencer [24] and modified by Tan [23]. Ten grams of soil sample were extracted with 50 mL of 1 M ammonium nitrate solution. After shaking for thirty minutes, the extract was filtered through Whatman No.2 filter paper and then filtrate was used for the analysis of potassium. The available phosphorous in soil sample was estimated by method as described for acidic soil by Bary and Kurtz, [25] modified by Jaiswal [26].

The micronutrients (Mn, Fe, Cu, and Zn) in each soil sample were determined by the method described by Lindsay and Novell, [27]. In this method diethylenetriaminepentaacetic acid (DTPA) was used as extractant and the micronutrients in the extract were determined by Atomic Absorption Spectrophotometer.

All the chemicals used in the study were procured from Merck India Pvt. Ltd. All the tests were performed in triplicate.

## 3. RESULTS AND DISCUSSION

Basic analytical data for important physicochemical properties, macronutrients and micronutrients of surface soil samples are presented in Tables 1 to 3, in term of minimum, maximum, mean, median, sum of the values ($\Sigma_n$) sum of square values ($\Sigma n^2$), population standard deviation ($\sigma_n$), sample standard deviation ($\sigma_{n-1}$) and variation. Correlation coefficient (r) between macronutrient and micronutrient with pH and OC (%) of soil samples are presented in Table 4.

### 3.1 Assessment of Physicochemical Properties of Soil

#### 3.1.1 pH

pH value is the measure of the hydrogen ion concentration in soil and reflect the health status of the soil as to know it is suitable for cultivation or not. It also determines the availability of nutrients, microbial activity and physical condition of soil [28] Soil in the study area was acidic, with pH ranging from 4.4 to 5.7 in and outside of tea garden belts with mean value 4.89 and standard deviation 0.4347 as shown in Table 1. Lowest value of pH (4.4) was recorded at G4 inside and highest value (5.7) was recorded at F5 outside of tea garden (Fig. 2). The study revealed that pH of majority of soil samples was below the permissible range of irrigated water (6.0- 8.5) The data revealed that soils inside were more acidic compare to paddy fields by the leaching effect of rain water during summer, which replaces basic cations ($Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$) with the $H^+$ ion. Use of long term inorganic fertilizers instead of green manure, farmyard manure had also enhanced in decreasing soil pH [29]. The constant addition of fertilizers like ammonium sulfate and super phosphate in tea garden can play a vital role to change pH condition in soil, is also supported by Barush et al. [30]. The continuous use of agrochemical in the soils may affect the nutrient uptake of the tea plant. The repeated use of N- based fertilizers makes the soil acidic. This acidification creates so many problems such that loss of balance in population density of soil microorganism, loss of cationic nutrients and increase Al (III) toxicity [31].

The acidic soil pH favors the uptake of micronutrients (Mn, Fe, Cu and Zn) and causes harmful effect to the plants and human beings through food chain [32,33]. Since the pH of soil in the study areas was found to be acidic, therefore uptake of micronutrients by plant was high and the biological system was contaminated by the micronutrient metals, was also supported by T. Nath [34]. Due to low value of soil pH than permissible limit (6.0-8.5), $NO_3^-$ - N and $NH_4^+$ - N becomes less available to plant and availability of N, P, K, Ca, and Mg also decreases with decrease in soil pH in the study areas [35]. The uptake of micronutrient by plant under acidic nature of soil in the present areas showed a considerable variation with the rainfall distribution, relative humidity and temperature variation [33].

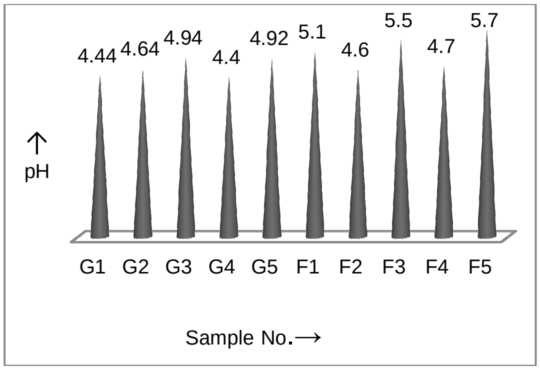


**Fig. 2. Variation of pH**

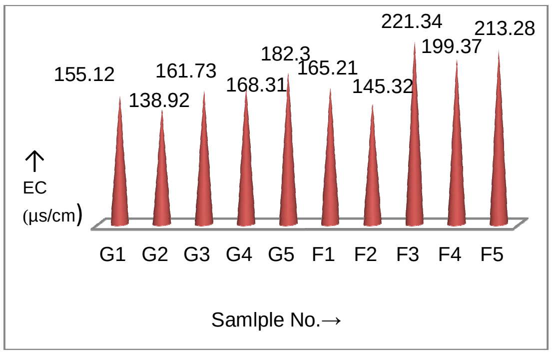


**Fig. 3. Variation of EC**

### 3.1.2 Electrical Conductivity (EC)

The EC values varied between 138.92 - 221.34 µS/cm (Fig.3) with mean value 175.09 µS/cm (Table 1). The conductivity values suggested that soil in and outside of tea garden belts were in high ionic concentration. The relatively low soil conductivity in side of tea garden compared to outside (paddy field) was due to higher leaching induced by heavy rainfall in the absence of adequate amount of organic carbon matter or may be due decomposition of organic matter at high temperature as supported by Urkurkar et al. [36]. Whereas high values of EC in paddy field may be due to agricultural runoff from the tea gardens, domestic sewage and waste water disposal.

### 3.1.3 Soil organic carbon (OC %)

Organic carbon is directly related with soil organic matter which can be shown by the following equation [37]:

$$\text{Soil organic carbon \%} = \frac{\text{organic matter \%}}{1.73}$$

Therefore, decrease in soil organic carbon will cause decrease in soil organic matter. In the present study for soil total organic carbon (% C) in and outside of tea garden were found to be 0.76-1.81% as shown in Fig. 5 with mean value 1.335% and standard deviation 0.4184 (Table 1). Observed values of organic carbon showed that all samples collected from in and outside of tea garden were within safe limit as compared by chemical rating chart (0.5-0.75% C) as recommended by ICAR 2005 [38].

The soil productivity is determined primarily by organic matter. It provides food for microorganism, to maintain the soil fertility, takes parts in chemical reaction such as ion exchange, governs the physical properties of soil and sometimes carry out biological weathering of rocks. The biologically active components of organic matter consist of polysaccharide, amino sugar, nucleotides, organic sulfur and phosphorous compounds. Therefore, organic matter in soil acts as storage for all the available nutrients of the plant [39]. In tea plants, low organic carbon in soil affects yield product and use of other nutrients by the plant system [40]. Thus, due to lower organic C% imbalance of nutrients develop in the plant system.

The results revealed that agricultural soil of study area promote soil aggregation, prevent loss of nutrients and enhance the mineralization of organic N, P and K making a suitable environment for plant growth [41]. High value of organic carbon inside of tea garden may be due to addition of chemical fertilizers, animal wastes and tea leaves into the soil. Use of green manure, domestic waste products, farmyard manure and rice-straw residue in conjunction with fertilizer in paddy field (outside of tea garden) by the rural people of the study area might also increase organic carbon. Soil pH and high organic carbon matter content have a higher retention capacity of micronutrient metal in soil. For plant, carbon and sulfur are important nutrients for the life cycle and are cycled in the soil between organic matter and plant available nutrients [42]. Soil containing high organic carbon does not suffer from sulfur deficiency as sulfur mineralizes from the organic matter.

#### 3.1.4 Bulk density (BD)

The bulk density (BD) of the soil samples of the study areas varied from 0.94 – 1.28 g $cm^{-3}$ with mean value 1.127g $cm^{-3}$ (Table 1). The result showed that soil of the study areas cannot retain sufficient amount of available nutrients and water. Due to low soil bulk density and porosity inside tea gardens the rate of leaching of major cations was higher than paddy field which perhaps cause of low soil pH [41].

### 3.2 Macronutrient of Soil Samples

#### 3.2.1 Nitrogen

The range of nitrogen in the study area was found to be 255.25 to 431.21 kg/ha in and outside of tea garden areas (Fig. 4) with mean value 328.51 kg/ha and standard deviation 65.57 (Table 2), which are marginal according to the chemical rating chart (260 to 560 kg/ha) as recommended by ICAR 2005. The results showed that there is no visible environmental pollution due to nitrogen elements on soil because accurate proportion of nitrogen was added to the soil. A significant positive correlation (r = 0.956) was observed between nitrogen and pH (Fig. 8). Nitrogen also shows positive correlation (r = 0.493) with organic carbon (Fig. 9 and Table 4). Similar result was also reported by Singh and Mishara, [43] and T.N. Nath [34].

The high acidic nature of soil in and outside areas of tea garden prevents organic matter to break down, resulting in an accumulation of organic matter and tie up nitrogen. Nitrogen is important for growth because it is a major part of all amino acids, which are the building blocks of all proteins, including the enzymes, which control virtually all biological processes. A good supply of nitrogen stimulates root growth and development, as well as the uptake of other nutrients. The consumption of nitrogenous fertilizer makes the soil acidic and in acidic soil the bacterial population decreases but the population of fungi increases relatively. It produces a microbiological imbalance [44]. Plants deficient in nitrogen tend to have a pale yellowish green color (chlorosis), have a stunted appearance, and develop thin, spindly stems [45].

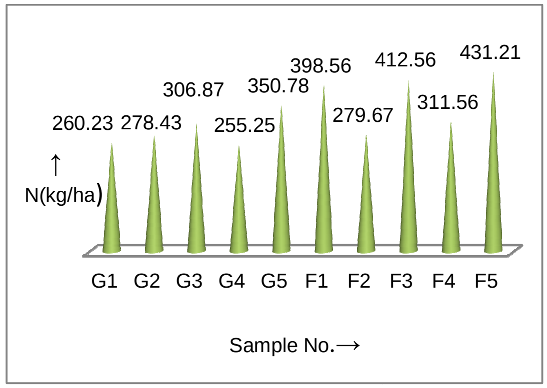


**Fig. 4. Variation of nitrogen**

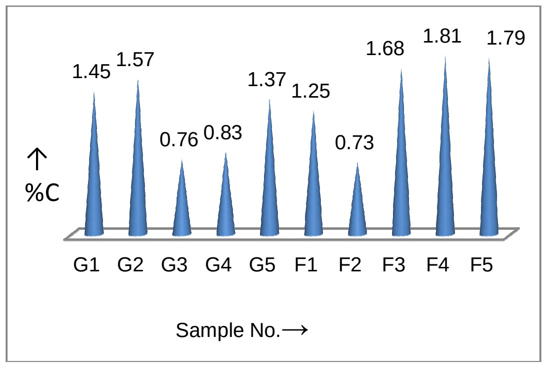


**Fig. 5. Variation of % (C)**

#### 3.2.2 Phosphorous

The range of phosphorous in the study area varied from 9.32 to 31.32 kg/ha with mean value 20.94 kg/ha and standard deviation 51.29 (Table 2) in and outside of tea garden areas, which are below the chemical rating chart (25 to 62 kg/ha) as recommended by ICAR 2005. In acidic soil, there is a tendency of low phosphorous levels over time. The low value of phosphorus in all soil samples of in and outside of tea garden may be due to fixation of phosphorous in unavailable form. Phosphorous was found to be positively correlated with pH with r value of 0.878 (Fig. 8). A positive correlation (r =0.380) was also found between phosphorous and OC % (Fig. 9). Similar trend of positive correlation was observed by Singh and Mishara, [43] and T.N. Nath [34]. Injudicious use of chemical fertilizers and pesticides in tea gardens and intensive cropping had resulted in lowering the potassium status of soil indicating the need to apply the potassium to meet the crop requirement.

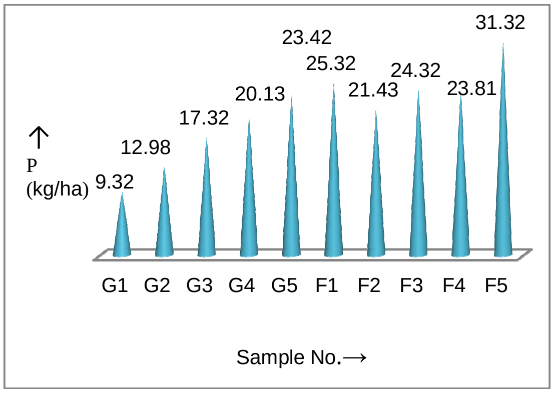


**Fig. 6. Variation of phosphorous**

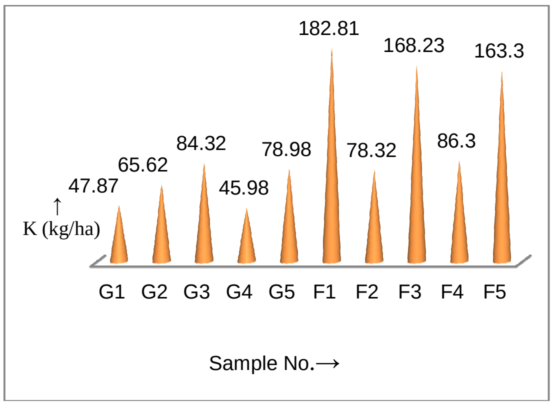


**Fig. 7. Variation of Potassium**

Phosphorous is essential element for many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production), and maturation [46]. It is taken by plants as soluble orthophosphate i.e. $H_2PO_4^-$ and $HPO_4^{2-}$ and sometimes as soluble organic phosphorous. The $HPO_4^{2-}$ anion dominates in strongly acidic and $H_2PO_4^-$ anion in alkaline soils while both anions are in near-neutral soils. The repeated use of P-based fertilizers can make several cationic nutrients like Zn(II), Fe(II) / Fe(III) etc. unavailable because of the formation of their insoluble phosphate [e.g.$Zn_3(PO_4)_2$]. These insoluble phosphates cannot give the phosphorous required for plant growth. It may produce the metal ions deficiency along the food chain. Phosphorous-deficient plants are usually stunted, thin-stemmed, and spindly, but their foliage is often dark, almost bluish, and green. A phosphorous-deficient plant often seems quite normal in appearance and in severe cases, can cause yellowing and senescence of leaves [45].

### 3.2.3 Potassium

Potassium in the soils of inside and outside of the tea gardens of the study area are ranging from 45.98 to 182.81 kg/ha (Fig. 7), which are deficient and are not in according with rating (272-690 kg/ha as given by ICAR, 2005. A significant positive correlation (r = 0.730) was found between pH and K (Fig. 8). Potassium also showed positive correlation (r = 0.247) with OC %. This might be due to creation of favorable soil environment with presence of organic matter. Similar positive correlation was shown by several studies [45,47]. Potassium is required at high levels by growing plants. Potassium activates some enzymes in plants responsible for metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar degradation [46]. It plays a key role in the water balance in plants. It also helps plants adapt to environmental stresses. Potassium nutrition is also linked to improved drought tolerance, improved winter hardiness, better resistance to certain fungal diseases, and greater tolerance to insect pests. Potassium is relatively abound in the earth's crust, most of it not accessible to plants, only clay minerals in soil containing exchangeable potassium make it available to plants. Potassium is taken as a cationic nutrient $K^+$ that remains bound with the cation exchange sites of soil. As it bind less firmly with the soil cation exchanger sites, it is lost easily through leaching and plants experience its deficiency. Its deficiency causes the tips and edges of the oldest leaves to begin yellowing (chlorosis) and die (necrosis), so that the leaves appear to have been burnt on the edges [45].

**Table 1. Basic statistics for the physicochemical properties of soil samples in and around tea garden belt**

| Properties | Min | Max | Mean | Mean | Σn | $\Sigma n^2$ | $\sigma_n$ | $\sigma_{n-1}$ | Variation |
|---|---|---|---|---|---|---|---|---|---|
| pH | 4.4 | 5.7 | 4.894 | 5.01 | 8.95 | 241.21 | 0.4124 | 0.4347 | 0.1889 |
| EC(µS/cm) | 138.92 | 221.35 | 175.09 | 173.75 | 1,750.9 | 313719.5 | 6.748 | 28.195 | 794.96 |
| OC (%) | 0.76 | 1.81 | 1.335 | 1.31 | 13.35 | 19.298 | 0.3969 | 0.4184 | 0.175 |
| BD (g/cc) | 0.94 | 1.28 | 1.127 | 1.015 | 11.27 | 12.846 | 0.120 | 0.1267 | 0.016 |

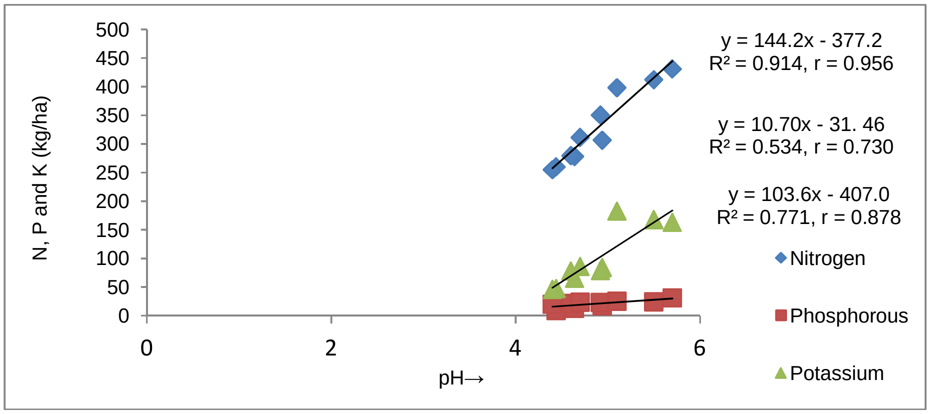


**Fig. 8. Correlation between pH with N, P and K**

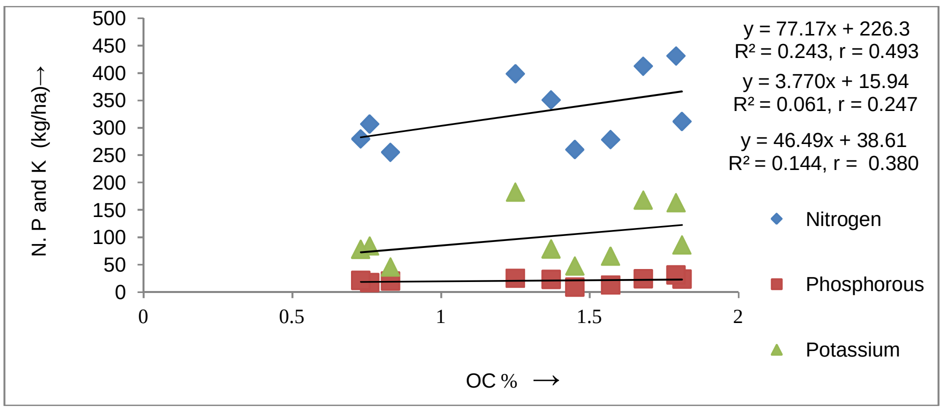


**Fig. 9. Correlation between OC (%) with N, P and K**

**Table 2. Basic statistics for the macronutrients (N, P and K) of soil samples in and around tea garden belt**

| Macronutrient | Min | Max | Mean | Median | Σn | $\Sigma n^2$ | $\sigma_n$ | $\sigma_{n-1}$ | Variation |
|---|---|---|---|---|---|---|---|---|---|
| N(kg/ha) | 255.25 | 431.21 | 328.51 | 374.67 | 3,285.12 | 111789.2 | 62.20 | 65.568 | 4299.16 |
| P (kg/ha) | 9.32 | 31.32 | 20.937 | 24.37 | 209.37 | 4,748.707 | 48.66 | 51.297 | 40.564 |
| K (kg/ha) | 45.98 | 182.81 | 100.17 | 130.89 | 1001.73 | 124028.8 | 48.66 | 51.297 | 2632.38 |

### 3.3 Micronutrient Content of Soil Samples

Mn contents in the soil samples varied from 130.12 - 412.71 mg/kg; Fe contents were 91.23 - 278.2 mg/kg; Cu contents were 14.99 - 29.67 mg/kg and Zn contents were found to be 22.12 - 46.13 mg/kg (Figs. 10, 11, 12 and 13). The concentration of micronutrient metals increased with increase of pH of soil. The pH showed that positive significant correlation with Mn, Fe, Cu and Zn with r value 0.90, 0.966, 0.949 and 0.957 respectively as shown Figs. 14, 15. Similar trend was observed by several studies [48-51].

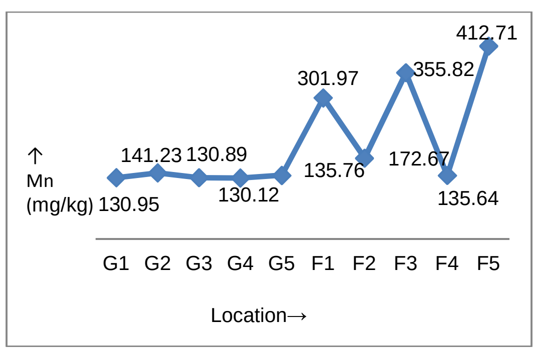


**Fig. 10. Variation of Mn**

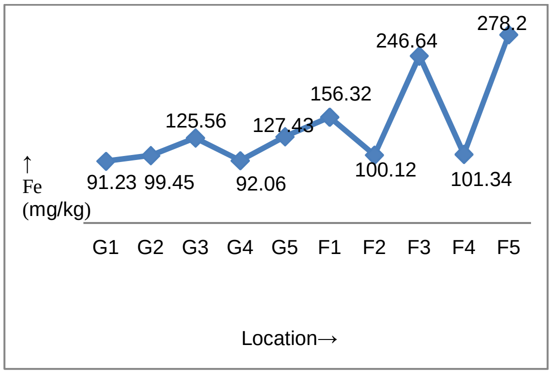


**Fig. 11. Variation of Fe**

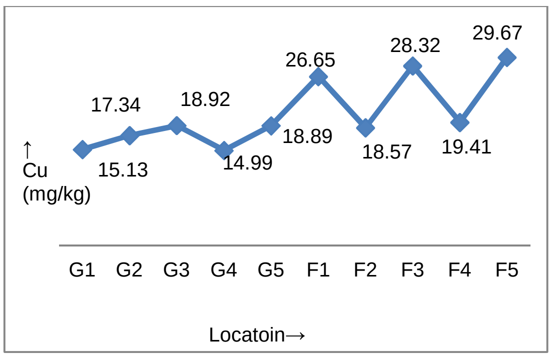


**Fig. 12. Variation of Cu**

The micronutrient metal uptake by plant decreases with increase of pH of soil. The pH of soil of study areas was found to be acidic, which favors the uptake and cause of harmful effect to soil, plants and animals. Thus uptake of these metals by plants in and outside of tea garden belt was high and the biological system was contaminated by the micronutrient metals. The results also indicate that soils having high organic carbon (OC %) had high level of concentration of micronutrients and their concentration increase with increase of % of organic carbon. The complexation type reaction takes between these metals and organic carbon which results in the retention of micronutrient metals in the soil. A linear positive correlation was observed between % of OC and Mn, Fe, Cu, Zn (Figs. 16 and 17) which was supported by several researchers [48-51]. Low level of phosphorous plays an important role in the uptake of Mn, Cu [52]. Mehrang et al. [53], also reported that plant take up metal by the phosphate pathway due to their chemical similarity. Copper and Zinc were found to be good source of protein [54]. Low concentration of Cu and Zn are required for proper functioning of most of the plant system but their higher concentration may be the cause for metabolic disturbance and growth inhibition of some plants. The soluble forms of micronutrient metals are dangerous as they are easily and readily available to plants and animals [55].

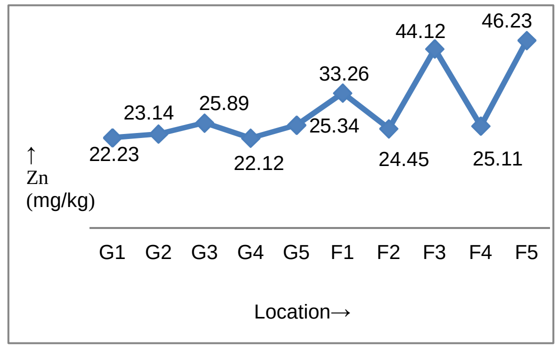


**Fig. 13. Variation of Zn**

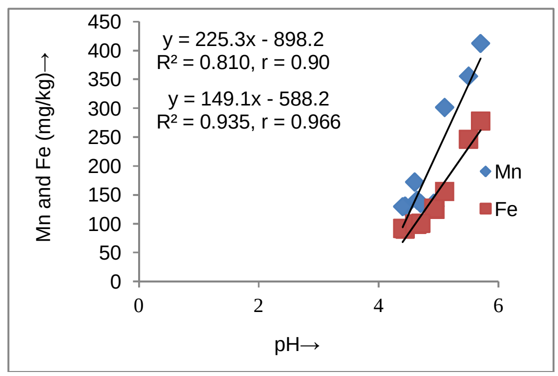


**Fig. 14. Correlation between pH with Mn and Fe**

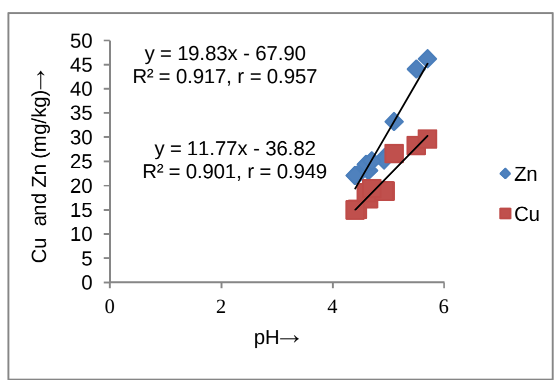


**Fig. 15. Correlation between pH with Cu and Zn**

**Table 3. Basic statistics for the micronutrients (Mn, Fe, Cu and Zn) of soil samples in and around tea garden belt**

| Micronutrient | Min | Max | Mean | Median | Σn | $Σn^2$ | $σ_n$ | $σ_{n-1}$ | Variation |
|---|---|---|---|---|---|---|---|---|---|
| Mn (mg/kg) | 130.12 | 412.7 | 204.776 | 218.86 | 2047.76 | 525924.4 | 103.243 | 108.828 | 22843.5 |
| Fe (mg/kg) | 91.23 | 278.2 | 141.835 | 141.87 | 1418.35 | 241648.26 | 63.62 | 67.0626 | 4497.04 |
| Cu (mg/kg) | 14.99 | 29.67 | 20.789 | 22.77 | 207.89 | 4583.238 | 5.1128 | 5.38942 | 29.045 |
| Zn (mg/kg) | 22.12 | 46.23 | 29.189 | 29.30 | 291.89 | 9249.664 | 8.5422 | 9.0042 | 81.07 |

**Table 4. Correlation coefficient (r) between macronutrient, micronutrient with pH and OC (%) of soil samples**

| Soil Properties | N | P | K | Mn | Fe | Fe | Zn |
|---|---|---|---|---|---|---|---|
| Soil pH | 0.956 | 0.878 | 0.730 | 0.900 | 0.966 | 0.949 | 0.957 |
| OC | 0.493 | 0.380 | 0.247 | 0.437 | 0.478 | 0.457 | 0.489 |

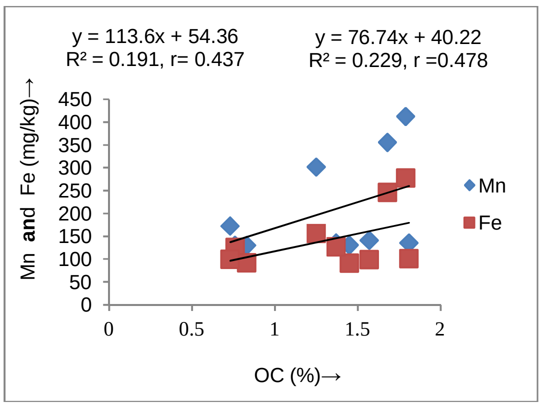


**Fig. 16. Correlation between OC (%) with Mn and**

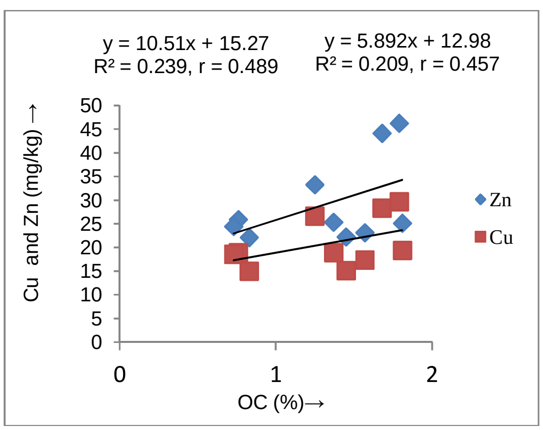


**Fig. 17. Correlation between OC (%) with Cu and Zn**

## 4. CONCLUSION

Finally, it is concluded that continuous removal of nutrients from soil in and around tea garden belts (paddy field) through different sources requires continuous fertilization to maintain soil fertility and productivity. The fertilization requires specific knowledge in order to get maximum yield, minimum cost and to reduce adverse effect of soil and crops. Among various parameters pH, OC (%), available N, P K and micronutrients such as Mn, Fe, Cu, and Zn are most sensitive parameters, which have direct effect on productivity and fertility of soil. From the experimental data it is revealed that soil in and around the tea gardens of Belwa of Kishanganj district is not accordance with fertility rating chart as recommended by ICIR (2005). Soil of study areas is acidic which favor high uptake of micronutrients which may cause harm to animals, plants and human beings. This study suggest that without reconciling of local and scientific knowledge among tea growers and farmers, satisfactory level of crop production and maintenance of soil fertility cannot be improved at the same time.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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