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Soil Nutrient Status in Different Tea Gardens of Tinsukia District of Assam

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Abstract

A field study was conducted to evaluate the effect of land use change from forest to tea cultivation on soil acidification as well as on soil parameters *viz*. organic carbon (OC), nitrogen (N), phosphorus (P) and potassium (K). A total of 120 surface soil samples (0–20 cm) were collected from the representative tea gardens of Tinsukia district, Assam, India. The soil acidification, organic carbon and nutrient concentration in soil at different fertilizer input levels i.e., high commercial fertilizer application (Jitani tea garden), low input commercial fertilizer+organic fertilizer (Agarwal Tea Garden) and organic fertilizer (Udayachal Tea Garden) and adjacent forest were measured in soil laboratory of Krishi Vigyan Kendra, Tinsukia. Tea cultivation caused soil acidification on increasing the application of chemical fertilizer. Lowest pH (3.1) was observed in soils of high commercial fertilizer application. Compared to the forest soil, significantly lower concentration of soil organic matter (0.35%) and nitrogen (207.56 kg ha^{-1}) was observed in various tea plantations. Soil phosphorus was observed highest (45.76 kg ha^{-1}) in organically treated soil as compared to forest soil and other two tea plantations. High potassium concentration (173.73 kg ha^{-1}) was observed in chemically treated garden.

Keywords: Fertility, organic matter, soil acidity, tea garden

1. Introduction

Tea (*Camellia sinensis* L.) is the most consumed manufactured drink worldwide and is widely planted in tropical and subtropical areas of the World. It is the cheapest non-alcoholic beverage made from young leaves and buds. Assam, a northeastern state of India plays a major role in the Indian tea industry by contributing about 53% of the country's and around 17% of the world's total annual tea productions (Dikshit and Dikshit, 2014). Assam has the largest tea-growing region in the world with a record number of 68,465 small tea gardens (area of 3–15 acre) and 825 large tea gardens (15 acres) (Anonymous, 2014). Tea is a perennial evergreen shrub growing in tropical, subtropical and temperate climate (Anonymous, 1976). Apart from the temperature and precipitation, soil is the most limiting factor, which influences growth and ultimate yield of the tea plants. Soil nutrient plays a vital role in tea cultivation. Nutrient management of plantation crops has greater importance particularly to sustain and improve soil health. In a given locality, however, soil characteristics as well as nutrient parameters play a significant role for sustainable tea production (Hamid et al., 2004; Sarwar et al., 2011).

Intensive agriculture without adequate and balanced use of chemical fertilizers, non-ecofriendly tillage practices, and with little or no use of organic manure caused severe fertility deterioration of our agricultural soils resulting in stagnating or even declining of crop productivity (Barua and Bora, 1975). Such declining in tea leaves productivity has been reported from various small tea gardens of Assam in recent years. In general, the tea bushes prefer acidic soils with a pH range of 4.5–6.0. But, continuous and exhaustive cultivation and application of large amount of chemical fertilizer and herbicides have led to the deterioration of soil health resulting in an increase in soil acidity and aluminum toxicity. A recent study by Bandyopadhyay et al. (2014) highlighted the alarming increase of soil acidity in the tea gardens, ranging from very strongly acidic (pH 4.9) to extremely acidic (pH 4.4) condition with low cation exchange capacity and low base saturation status (>35%). Acidic soils are generally poor in fertility and water holding capacity.

Tea plants are known to be typical Al accumulators and can take up large amounts of Al, most of which is accumulated in the leaves. Biogeochemical cycling of Al in tea litter may also cause soil acidification in tea plantations (Ding and Huang, 1991); however, most studies have attributed soil acidification in tea plantations to heavy application of chemical fertilizer (Abe et al., 2006; Oh et al., 2006; Ruan et al., 2006). Application of ammonium ($NH4^+$)–N fertilizers to increase yields of tea can greatly accelerate soil acidification through nitrification of $NH4^+$ (Ruan et al., 2000, 2004; Oh et al., 2006). Researchers have found that wide application of synthetic N fertilizers can cause soil acidification and the depletion of base metal cations in terrestrial ecosystems (Bolan et al., 1991; Barak et al., 1997; Bowman and Cleveland, 2008). As most tea planting areas are highly acidic and well drained (Ruan et al., 2013), evidence suggests that acidic soils would experience stronger acidification under excessive N additions (Alekseeva et al., 2011). Tea bioactive ingredients are widely considered to have human health benefits such as controlling blood pressure and glucose levels (Hodgson et al., 2013; Zheng et al., 2013; Weerawatanakorn et al., 2015), promoting fat oxidation for weight management (Dulloo et al., 1999) and causing relaxation effects (Juneja et al., 1999). An unbalanced soil nutrient status can limit plant growth and biochemical ingredient formation (Li and Xia, 2005). N fertilizer addition has been shown to increase tea shoot yield by enhancing of soil N availability, while excessive N application may decrease tea quality (Qiao et al., 2018).

Soil organic matter (SOM) is another important for soil fertility and soil mineralization. SOM contain the main nitrogen stock, nearly the half of phosphorus, significant part of sulphur and other macro and micro nutrients for sustaining life and productivity of plants (Saljnikov et al., 2013). Researchers have found that tea cultivated with bio-organic fertilizers has superior colour and taste compared to tea treated with chemical fertilizers (Lin et al., 2010; Zhang et al., 2012). Studies have also suggested that the use of organic fertilizers resulted in higher seedling biomass and significantly improved the soil fungal to bacterial ratio as well as soil enzyme activity (Sun et al., 2017; Xu et al., 2010). In addition, while long-term application of chemical fertilizers could lead to serious soil acidification, nutritional imbalance, and deterioration of the rhizosphere micro-ecological environment, further increased the activity of heavy metal ions in soil. The use of organic fertilizer could alleviate soil acidification, resulting in increased plant yields (Li et al., 2018). Organic fertilizer can help to shape the microbial composition and recruit beneficial bacteria into the rhizosphere of tea, leading to improved tea quality and reduced heavy metals content in rhizosphere soil and tea leaves (Lin et al., 2019).

In this study, total 120 numbers of soil samples from three tea gardens with different cultivation practices were sampled and analyzed. The objectives of this study were to evaluate the effect of agronomic management practices on 1) soil acidification 2) soil organic matter content and 3) soil available N, P_2O_5 and K_2O of the garden soil.

2. Materials and Methods

2.1. Field sites

The study was located in Tinsukia district of Assam, India which is the land of thousands of small tea growers famous for producing very good quality Assam tea. Tinsukia district extends from tropical longitude 27° 30′ to 27.5° North and 94° 22 ′ to 94.37° East longitudes and average elevation of 116 m above the mean sea level (MSL). This district of Assam is 84 km away from the border of Myanmar. The environment and experiment site is characterized by subtropical monsoon climate with cold winter, spring, rainy and humid summer. The average annual rainfall of Tinsukia district is 1950 mm approximately with a total number of 132 rainy days. The soil is found usually acidic in nature. Tea is abundantly grown in old alluvial soil of the district having pH in the range of 4.2–5.5 with a very low quantity of exchangeable calcium and soluble magnesium. The forest of this district falls under evergreen and typical rainforest blessed with rich flora and fauna.

Three tea gardens with different fertilizer input levels i.e., high commercial fertilizer application (Ranjit Jitani tea garden), low input commercial fertilizer+organic fertilizer (M/s Agarwal Tea Garden) and organic fertilizer (Udayachal Tea Garden) and adjacent forest were selected to analyze the effect of fertilizer input on soil acidification, organic carbon content, N, P, K content of soil. Soil sample analysis was done in the soil laboratory of Krishi Vigyan Kendra, Tinsukia of Assam Agricultural University.

2.2. Soil sampling and analysis

The soil samples were collected during the period between October to February of the year 2017–18 in Tinsukia district of Assam, India. A total of 120 surface soil samples (0–20 cm) were collected from the representative tea gardens of Tinsukia district. The area of each tea garden was divided into ten plots and from each plot, four number of soil samples were collected. Samples from at least five points were homogenized to form a composite sample. Soil samples were performed after tea picking and before fertilization and top soil was dug under the canopies of tea bushes. After collecting, 1.0 kg of each soil sample was stored in self-sealing plastic bags and sent to laboratory and dried naturally. Plant residues, roots and stones were removed and soil samples were passed through a 2 mm sieve.

Soil chemical properties were determined by analyzing soil pH (1:2 soil water ratio), organic carbon (OC) by Walkey and Black method as outlined by Jackson (1967), available nitrogen by alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus by Olsen method (Olsen et al., 1954) and available potassium by Flame Photometer method (Hanway and Heidal, 1952).

2.3. Data analysis

Data from the different tea gardens were analyzed using one way ANOVA at 0.01 level of probability using SPSS V. 16. Pearson's correlation analysis of soil parameters was done to ascertain the relationship between the variables.

3. Results and Discussion

3.1. Soil pH

Soil pH for tea plantation is considered best between pH range of 4.5–5.5. In our study, forest soil recorded higher average pH value (4.9) with a pH range of 4.35–5.6 than the other samples (Table 1). Only 12.5% of total soil sample collected from forest soil were recorded under critical pH value 4.5. The average pH value of organic (Udayachal) tea garden was 4.6 with the pH range 5.33–4.4 and 30% of total sample was recorded under 4.5 pH value which is the critical pH value for tea cultivation. The soil pH value decreased with increase in chemical fertilizers for a longer time. The lowest soil pH value was observed 3.81 in INM (Agarwal tea garden) whereas 3.1 in Chemical fertilizer (Jitani Garden). It was also observed that 65% of total number of samples under INM (Agarwal tea garden) and 70% of chemical fertilizer (Jitani garden) were found under the critical pH limit 4.5. This may be due to the long term organic or chemical fertilizer treatment in the tea garden, which showed significant differences in soil chemical properties. Soil pH of tea cultivation areas was found significantly (F=28.87, $p<0.01$) lower that the forest soil pH. The pH value of organic tea garden was near to the value of forest soil, but the pH value of chemical fertilizer tea garden and INM treated tea garden were significantly lower than the virgin forest soil. This may be due to the effect of continuous applied fertilization in the process of tea cultivation and the root metabolism of the tea tree causing acidification in the rhyzospheric soil (Zhang, 2018). Soil and plant processes associated with the carbon and nitrogen cycles are considered to be the main sources of acids in the tea garden systems (Yan et al., 2018). The excretion of organic acids such as oxalic acid, citric acid and malic acid is the main interior proton source for soil acidification in tea garden (Yang, 2005). The high input of nitrogenous fertilizer is another factor that causes soil acidification (Guo et al., 2010). In our study, the lowest pH value was observed in the soils of high input tea garden (4.2) which is lower than the critical pH value for tea plants. This may be due to extensive use of chemical fertilizers and lack of organic input, which is useful as a means to preventing soil acidification (Butterly et al., 2013). In this study, soil pH in medium input was observed more than the value of high input gardens. This may be due to application of organic input along with chemical fertilizers, which helps in preventing the soil acidification. In case of organic input gardens, soil pH was observed favourable for the tea cultivation (4.6). Organic fertilizer treatments improve soil pH and increase the contents of tea polyphenols and amino acids in soil (Lin et al., 2019). The application of organic fertilizer and the addition of tea pruning shoot residues to the topsoil are believed to increase the soil organic matter which can exert a buffer effect to prevent soil acidification (Li et al., 2016).

Table 1: Chemical properties of soils collected from forest land and different tea gardens

Parameters	Range and mean	Forest soil	Udayachal garden	Agarwal garden	Jitani garden
pH	Range	4.35-5.6	4.4-5.33	3.81-5.23	3.1-5.3
	Mean±SD	$4.99±0.40^{a}$	$4.6±0.26^{b}$	$4.38±0.31^{c}$	$4.27±0.47^{c}$
OC %	Range	1.0-1.85	0.76-1.25	0.11-0.8	0.06-0.73
	Mean±SD	$1.43±0.23^{a}$	$0.98±0.15^{b}$	$0.56±0.15^{c}$	$0.35±0.17^{d}$

Dissimilar alphabets (a, b, c, d) in superscript indicate statistically significantly differences ($p<0.01$); pH: Soil pH; OC: Organic carbon

3.2. *Organic carbon*

Organic carbon content of forest soil varied from 1.13 to 1.83% with an average value of 1.43%. This organic matter content in soil significantly (F=282.78, $p<0.01$) decreases with the type and nature of fertilizer applied. Organic matter content in the soil of organic input garden (Udayachal garden) ranged from 0.76 to 1.25% with an average of 0.98%. Organic matter content in low input garden (Agarwal garden) soils was observed ranging from 0.11 to 0.87%, with an average of 0.56%. Least organic matter content was reported from the high input tea garden (Jitani garden) soil ranging from 0.06 to 0.73% with an average of 0.35% indicating very low organic matter in soil.

As the forest litter contributes very good organic matter content into soil, forest soil of the district was found with very high soil organic matter content. Like other crops, tea plants also require very good amount of organic matter. Soil organic matter promote soil aggregation, prevent losses of nutrient, and enhance the mineralization of organic N, P and S making a suitable environment for plant growth (Palm et al., 2007). In organic input garden (Udayachal garden), soil organic matter content (0.98%) was observed suitable for tea cultivation as organic matter were applied in such soil externally. In our study, soil organic matter content decreased significantly with the increase in high input fertilizer. This is due to the low use of organic fertilizer in the plantation and the deterioration of soil ripening (Zhang, 2018).

3.3. *Available nitrogen content*

The soil available nitrogen content was usually used to reflect the fertility and nitrogen supply of the soil. The soil nitrogen content of the forest soil ranging from 368.9 to 580.2 kg ha^{-1} with an average of 471.5 kg ha^{-1} which indicate very rich nitrogen content in soil. The average available nitrogen content in organic input garden (Udayachal garden) was observed 365.28 kg ha^{-1} ranging from 307.7 to 430 kg ha^{-1} indicating medium availability of nitrogen in soil. The available nitrogen concentration decreased significantly (F=268.56, $p<0.01$) in medium input (Agarwal garden) and high input

(Jitani garden) with the average values 259.9 and 207.6 kg ha^{-1} respectively (Figure 1).

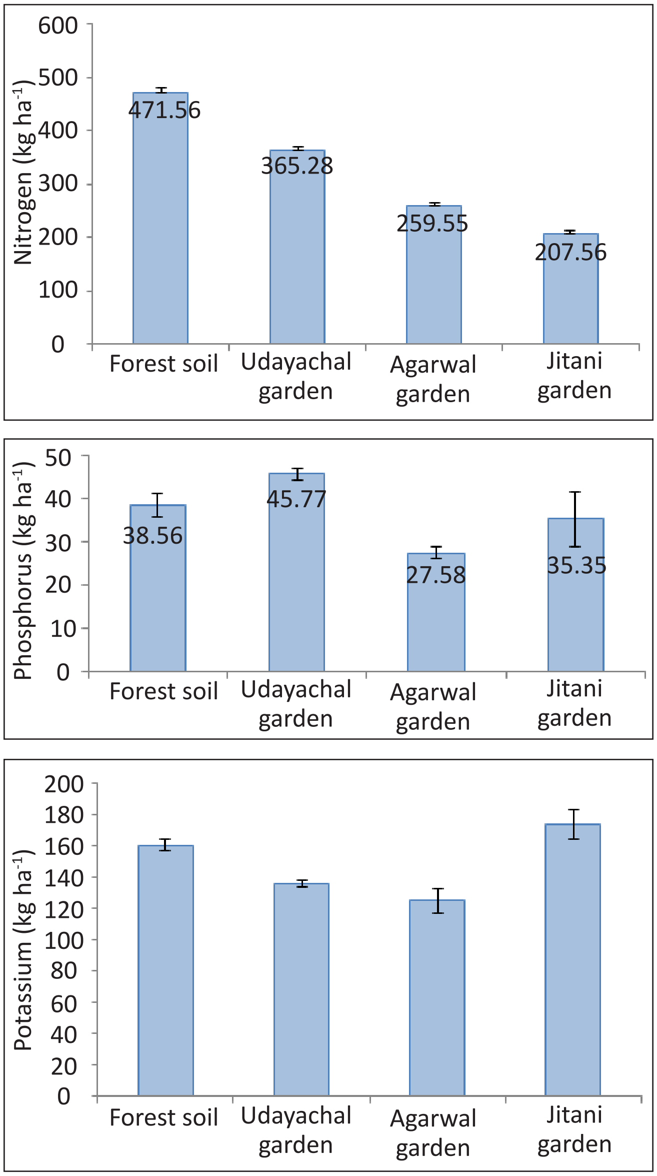

Figure 1: Nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}) and potassium (kg ha^{-1}) content in forest soil, Udayachal garden, Agarwal garden and Jitani garden

In our study, it was observed that nitrogen content in organic input garden soil was suitable for tea cultivation with addition of organic matter in soil. But in case of medium and high input garden, though the chemical nitrogenous fertilizers were applied with high dose, available nitrogen content was found less compared to forest soil and organic input garden soil. This may be because of heavy leaching loss of nitrogen caused by poor soil condition. Most tea farmers apply a large amount of nitrogenous fertilizer as an insurance against low yield and quality (Ma et al., 2013). Moreover, ammonia volatilization is very low in acidic soil and the N_2O emission factor of tea garden is about 2.9% (Fan et al., 2015). Overall, this can lead to a high rate of N enrichment in soil, which can leach further from the root zone to deeper soil due to the high rate of precipitation.

In future, tea plantation can reduce the amount of fertilizer, which could not only reduce the planting cost, reduce the agricultural non-point source pollution caused by excessive nitrogen fertilizer, but also prevent the nitrate content in the tea from exceeding the standard, thus improving the tea quality (Zhang, 2018).

3.4. Available phosphorus content

A significant (F=4.22, p<0.01) decrease in phosphorus level was observed in tea garden soil as compared to forest soil (Figure 1). The soil available phosphorus content of forest soil was observed as 38.56 kg ha^{-1} with a range of 12.51 to 82.32 kg ha^{-1}. It was 45.77 kg ha^{-1} in organic input garden (Udayachal garden) soil. In our study, average available phosphorus in medium input garden (Agarwal garden) soil and high input garden (Jitani garden) soil were recorded as 27.58 and 35.35 kg ha^{-1}, respectively (Figure 1).

Normally, soils of Tinsukia district of Assam are deficient in available phosphorus. Consequently, high rates of P fertilizers are often applied annually in tea garden to increase the soil fertility. Similarly, application of high amount of organic matter year after year also contributes a major portion of available phosphorus in organic input garden soils. In our study, the soil available P concentration of the tea gardens was almost same with those of forest soil. These results are in conformity with the study of Yan et al. (2018).

3.5. Available potassium content

The soil available potassium in forest soil was significantly (F=13.11, p<0.01) higher (160.62 kg ha^{-1}) than the garden soils. In organic input garden soil, it was between 110.3 kg ha^{-1} and 157.2 kg ha^{-1}, with an average value of 136.9 kg ha^{-1}. The available potassium content in medium input garden soil was observed between 19.31 to 240.2 kg ha^{-1}with an average of 125.09 kg ha^{-1}. In high input garden soil, it was between 64.49 and 288.9 kg ha^{-1}, with an average of 173.74 kg ha^{-1} (Figure 1).

In our study, the content of available potassium content was higher in chemical fertilizer applied garden soils. This may be due to the heavy doses of potassic fertilizers applied annually. The range of available potassium in medium input garden soil (19.31–240.2 kg ha^{-1}) and high input garden soil (64.49–288.9 kg ha^{-1}) is higher than the organic input garden soil (110.3–157.2 kg ha^{-1}). This showed a fluctuation of available potassium content in the soils of chemical fertilizer applied gardens. These results are in conformity with the findings of Zicheng et al. (2012).

3.6. Correlation analysis

Pearson correlation coefficients were performed to analyze the correlation between variables, including pH, OC, N, P and K content of soil (Table 2). The correlation with OC (r= 0.55**) and N (r=0.543**) suggested that OC and nitrogen have

Table 2: Correlation coefficients of the soil properties

	pH	OC%	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}
pH	1	0.55**	0.543**	0.052	0.041
OC (%)		1	0.997**	0.157*	0.014
N (kg ha^{-1})			1	0.162*	0.1
P (kg ha^{-1})				1	-0.084
K (kg ha^{-1})					1

**: Correlation is significant at the 0.01 level (2-tailed);
*: Correlation is significant at the 0.05 level (2-tailed)

a tendency to accumulate with increasing pH. Significant positive correlation was found between OC with nitrogen content (r=0.997**) and between OC and phosphorus (r=0.157*). Similarly, a significant positive correlation was observed between nitrogen and phosphorus (r=0.162*). There was no significant correlation found between potassium and other soil properties.

4. Conclusion

Changes in methods of tea cultivation often affect the properties of soil. By analyzing soil nutrient status in different tea plantations along with nearby forest soil, serious acidification was found to be caused by intensive tea cultivation. In our study, tea garden with organic treatment showed better soil condition compared to the chemically treated tea garden soil.

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