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Major Soil Chemical Properties of the Major Tea-Growing Areas in India

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ABSTRACT

Major chemical properties of tea-growing soils are of paramount importance for better management in a sustainable fashion. Therefore, this study was carried out to understand the major soil chemical properties of major tea (*Camellia sinensis* L.)-growing areas, Dibrugarh and Tinsukia districts, in the state of Assam, India. A total of 991 surface soil samples were collected from 15 large tea estates (TEs) for analysis of their major chemical properties. Soil pH ranged from 3.61 to 6.81. Total organic carbon and total nitrogen ranged from 2.4 to 47.3 and 0.24 to 3.60 g kg^{-1}, respectively. All soils were sufficiently rich in plant-available potassium (as K_2O), which ranged from 127.71 to 252.33 mg kg^{-1}, exceeding the amount prescribed for optimum tea yield of $\geq$ 100 mg kg^{-1}. Plant-available sulfur among soil samples widely varied from 4 to 129 mg kg^{-1}. Results of hierarchical clustering analysis for homogenous grouping of the 15 TEs based on soil chemical properties showed that the 15 TEs could be classified into three distinct groups which consisted of 6, 8 and 1 TEs, respectively. Based on the Kolmogorov-Smirnov (K-S) test, the best fitted theoretical probability distributions were found out for different soil chemical properties. It could be concluded that a balanced fertilizer application would be needed as a part of tea improvement program using soil chemical test.

Key Words: organic carbon, plant-available potassium, plant-available sulfur, probability distribution, soil pH, tea estates, total nitrogen

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INTRODUCTION

Among the beverages, tea (*Camellia sinensis* L.) is a widely consumed popular medicinal, aromatic, non-alcoholic, comparatively less expensive, healthy and stimulating beverage (Sharangi, 2009; Karak and Bhagat, 2010; Karak *et al*., 2011; Li, X. *et al*., 2013). Over two-thirds of the world's population drink tea and about 18 to 20 billion cups of tea are consumed daily in the world (Fernández-Cáceres *et al*., 2001) as it promises a lower risk of several diseases (Tomata *et al*., 2012). At present, tea grows in more than 45 countries, spreading within the latitudinal range of 45° N to 34° S (Barua, 2008), covering a total area of about 3.94 million ha globally (FAO, 2007). Total tea-cultivated area in India is 0.58 million ha, which accounts for 14.72% of total tea-cultivated land in the world (Basu Majumder *et al*., 2010). Assam, a state in India, extending from 89°42′ to 96° E longitude and 24°8′ to 28°2′ N latitude, is blessed with favorable soils and climatic conditions for tea cultivation. This is also reflected by the state's major share of tea-cultivated land covering an area of 0.32 million ha in India. Assam alone produces more than 50% of the tea produced in India, *i.e.*, 487.5 million kg per year, which accounts for about 14% of the world's total tea output (Tea Board of India, 2009). Moderately hot (13 to 32 °C) humid climate and well-drained fertile acidic soils (pH between 4.5 and 5.5) are favorable climatic and soil conditions for tea cultivation. Tea plants normally take 10–11 years to attain the optimum bearing stage, are considered most productive up to an age of 30–35 years, and continue to be productive up to the age of 70 years. As tea is a perennial plant, the cultivation-induced changes in a soil can be assessed by examining changes in properties of the soil. Several research findings corroborate the fact that nutrients in tea-growing soils get depleted after long-term cultivation (Kamau *et al*., 2008b; Oh

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et al., 2008; Wang *et al.*, 2013). It is apparent that the most important soil chemical properties, *viz.*, pH (Wang *et al.*, 2013), total organic carbon (TOC) (Han *et al.*, 2007), total nitrogen (TN) (Oh *et al.*, 2008), plant-available potassium (K) (Kamau *et al.*, 2008a) and plant-available sulfur (S) (Ananthacumaraswamy *et al.*, 2003), are having a major role in optimizing production of tea, like any other crops.

Even though moderately acidic soil pH is favorable for tea cultivation as mentioned earlier, detrimental effects on tea production and quality often occur as soil pH generally continues to decrease with the increase of stand age (Han *et al.*, 2007). It has been further proved by Xue *et al.* (2006) that pH values in soils are 4.22, 4.01 and 3.71 for 8-, 50- and 90-year-old tea gardens in China, respectively, indicating that the pH values of existing tea garden soils gradually decrease with time. Besides the age factor, other important pathways for accelerating soil acidification are the nitrification of NH_4^+ in the fertilizers supplied to tea plants (Guo *et al.*, 2010) and biogeochemical cycling of aluminum (Al) in tea litter (Wang *et al.*, 2010), due to the fact that tea leaves accumulate large amounts of Al (Karak *et al.*, 2015). Guo *et al.* (2010) have also concluded that anthropogenic acidification of Chinese tea garden soils is due to a practice of application of excessive levels of nitrogen (N) fertilization. Thus, it is recommended that soil pH should be adjusted for tea land by proper reclamation strategies based on soil pH measurement.

An important element of the agro-ecosystem is soil organic carbon (C). Munson *et al.* (2012) have reported that the benefits of soil organic C are linked closely to the facts that it is a good source of soil fertility and an energy source for soil microorganisms, acts as a storehouse for nutrients, contributes to soil aeration, reduces soil compaction, improves infiltration rates and increases water storage capacity. Although tea plantations accumulate less biomass than tropical forests and mature plantation trees, these perennial agroecosystems simply give rise to a sustained C sequestration in fragile areas (Kamau *et al.*, 2008a). It has been assumed that adaptation of tea bushes to abiotic stress (nutrient limitations, drought and cold) can be enhanced by aging of tea plantations. Kamau *et al.* (2008a) and Li *et al.* (2011) have concluded that quantifying C and nutrient stocks in soil will support to explore the response of tea plantations to such abiotic stresses, and offer new understandings for controlling interventions (uprooting, fertilization, irrigation). However, unlike the intensively studied C storage dynamics of forest systems (Bhattacharyya *et al.*, 2000; Nayak *et al.*, 2012), data on tea plantation C storage are scarce (Kamau *et al.*, 2008a; Li *et al.*, 2011).

It is apparent that tea, like any other crops, requires many nutrients for its growth. Nutrient requirements for commercial tea production are particularly high as succulent shoots, which are the harvestable portions of tea, contain the largest percentage of nutrients in the tea plant (Dang, 2005). Nitrogen is the most important and major nutrient element for tea cultivation as it is required in large quantities, accounting for approximately 5% of the dry weight of harvested shoots (Barooah *et al.*, 2005). Potassium is possibly the next most important nutrient after N, and made tea contains approximately 20 g K_2O kg^{-1} (Ranganathan and Natesan, 1985). Therefore, an average harvest of 3 000 kg ha^{-1} tea will remove around 150 kg N and 60 kg K_2O ha^{-1} $year^{-1}$ from soil. Besides N and K, S is one of the essential plant nutrients for tea growth and production (Ananthacumaraswamy *et al.*, 2003). A harvest of 3 000 kg ha^{-1} tea removes about 6 to 9 kg S ha^{-1} year (Sinha *et al.*, 1992). Additionally, large amounts of nutrients are locked in the bush frame of tea; parts of them, however, get returned to the soils through recycling of pruning litter. Furthermore, continuous uptake of nutrients by tea plants coupled with continued removal of produce leads to an overall negative nutrient balance at the farm level (Giller *et al.*, 1997). Therefore, a perfect understanding of the nutrient cycle is a prerequisite to gain a better understanding of tea cultivation (Dang, 2005).

Even though Indian tea acts as a fillip in the global market, a wide concern has been aroused over production decline of 12.6 million kg Indian tea in 2010 from that of 2009. However, this drop could have been checked to some extent by taking up proper precautionary measures such as best suited field practices, including application of optimum level of fertilizer based on proper soil testing and yield potential. Therefore, it is absolutely necessary to periodically examine the changes in the status of various soil chemical properties of the field at specific time intervals preferably in the pruning years (Barooah *et al.*, 2005). Then, it will be possible to determine potential deficiencies before they occur and take proper remedial measures to prevent acute deficiencies that cause serious shortfall in yield. Hence, it is better to test soil samples at the same time each year for consistency (Barooah *et al.*, 2005). This is also the common practice in the globally popular tea belt in major tea-growing areas in Assam, India. However, in spite of various studies on nutrient management in tea cultivation, very little or even no information has so far been available on the major soil chemical properties in major tea-growing areas of