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An Assessment of Nutritional Deficiency Symptoms in the Tea Plant (*Camellia sinensis* L.) Through Field Survey

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ABSTRACT

The most important factor in both plant development and productivity, which mostly depends on nutrient availability in the soil and environment, is the constituents of soil nutrients. Soil is always losing its nutrients by leaching, surface runoff as well as through harvesting and cultural operations like: pruning. For maintaining the balance of agricultural ecosystem fertilizer application is necessary to improve soil condition and gain better yield. In case of tea industry for maintaining better and uniform production applying fertilizer is a widespread management technique in worldwide. Tea requires a lot of macro and micronutrients for growth because it cannot be grown without the usage of fertilizer and other nutrient supplies. The purpose of this field survey was to ascertain the nutritional condition of tea leaves as well as the signs of nutrient deficiencies in tea plants. In this study, deficiency symptoms of the essential nutrients were found out at different tea estates of Moulvibazar and Sylhet districts as well as photographs were taken. Photographs of the nutrient deficient tea plants were correlated with the established symptoms. The range of total nitrogen, phosphorus, potassium, calcium, magnesium and zinc content in the collected tea leaf samples were 2.95- 5.18%, 0.28- 0.49%, 0.56-1.88%, 0.12-0.49%, 0.07-0.08% and 0.002- 0.004%, respectively.

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Introduction

Tea (*Camellia sinensis*) is an essential beverage cash crop planted under acidic soil conditions, which considerably contributes to the economies of various tea-growing countries in Asia, Africa, and Europe like Bangladesh, India, Sri Lanka, Kenya, Ethiopia, Georgia and Germany etc. According to De Costa et al. (2007), the tea plant can grow as high as 15 meters in the wild, but in cultivation, the crop is kept at 0.6m to 1.0m tall to make leaf harvesting easier. The soils condition differs from one country to another for tea plantation and the most important character is soil pH (Hajiboland, 2017). Tea grows best in a pH range of 4.5 to 5.8 (Zohora et al., 2022). The ideal soil conditions for tea growing are well-drained, deep, and well-aerated soil with 1% organic matter. (De Silva, 2007; Zohora et al., 2022). The other characteristics of soil including the soil's depth (less than 50 cm), slope of the field, graveliness (more than 50%) and rockiness (20%) of the soil have to be considered suitable for tea production with economic viability (Hajiboland, 2017).

Plant productivity is significantly influenced by the amount and caliber of nutrients present in the soil. The continuous removal of leaves from the soil during the tea-growing process gradually reduces the nutrients in the soil, requiring the plant to replenish those minerals (Tabu et al., 2015). Therefore, utilization of organic and inorganic fertilizers is essential. Chemical fertilizers are necessary for increased production and they can also increase both the quality and quantity of tea. A chemical element known as a “plant nutrient” is necessary for the vegetative and reproductive growth of plants. A plant cannot complete the vegetative or reproductive stages of its life cycle if it is lacking in a critical ingredient. This kind of shortage is particular to the element and can only be avoided by providing it. The element directly affects the plant's nourishment. Short supply of the essential nutrients results abnormal growth with deficiency symptoms of plants due to the result of the disruption of metabolism (Mengel & Kirkby, 2001). Therefore, to achieve higher tea production it is very important to know the functions of different nutrient elements, their status, deficiency symptoms, remedial measures of the deficiency of nutrients and critical limits in tea leaves which are presented in this article.

Materials and Methods

In 2023, a field survey was conducted in four tea plantations, including Marina, Saif, and Mazdehee tea estate in Moulvibazar district and Monipur tea estate in Sylhet district. Different nutrient deficiency symptoms of tea plants were identified in the tea field and photographs were captured. While conducting a field survey, 27 fresh tea leaf samples were taken from various tea fields on the estates for chemical analysis to measure nutritional content. Samples of fresh tea leaves were collected, cleaned in distilled water, and allowed to air dry. After that, leaf samples were oven dried for 48 hours at 80°C (Huq & Alam, 2005) and make them fine powder by using grinder. The leaf samples were digested by the nitric acid - perchloric acid (Huq & Alam, 2005). Using the Micro Kjeldahl steam distillation method, the total nitrogen was measured (Huq & Alam, 2005). A spectrophotometer (JENWAY 6300) was used to measure total phosphorus using the blue color method (Huq & Alam, 2005). The total potassium, calcium, magnesium, and zinc were measured using an Atomic Absorption Spectrophotometer (AAS) (Analytikjena, Model: novAA 400P).

Statistical Analysis

Microsoft Excel and IBM SPSS 20 were used to record and statistically analyze all of the data. One-way ANOVA, or the Analysis of Variance of Simple Classification, was used to evaluate the data, and treatments that were found to be significant were further examined using Tukey's post hoc test at the 5% level.

Results and Discussion

Plant Nutrient Elements

Even though there are more than 90 components in a plant, just 16 are thought to be necessary for healthy growth and development. Water or air is the sources of carbon, hydrogen, and oxygen. According to Ahmed et al. (2018), soil nutrient solutions provide the remaining 13 elements. The “macronutrients,” or elements needed in significant amounts, typically build up in plant tissues to levels of 1 mgg^{-1} dry weight and higher. Examples of these elements are calcium, magnesium, potassium, phosphorus, sulfur, nitrogen, and sulphur. Plants require small amounts of “micronutrients,” which can accumulate to less than 100 μgg^{-1} dry weight. Examples of these elements include iron, zinc, manganese, copper, molybdenum, nickel, boron, and chlorine. (Hajiboland, 2018).

Micronutrients are also known as trace elements which have specific functions connected with enzymes and co-enzymes**.** From the research discussion of Hajiboland (2018) and Ahmed et al. (2018) the classifications of essential elements can be presented in figure no 1.

Major Elements

Nitrogen (N)

Following carbon, nitrogen (N) is the most mobile and inadequate mineral element in soil and is essential to plant growth and development (Hawkesford et al., 2012). Nitrogen feeding increases tea productivity in a variety of environmentally advantageous situations without having any negative impacts from high N supply (Owuor, 1997). According to Khan et al. (2013), the critical limit for total nitrogen in tea soil is 0.1%. N accounts for 1% to 5% (10-50 mgg^{-1} dry weight) of total dry matter in plants. It promotes vegetative growth of tea plants and due to being constituent of protein, nucleic acid and chlorophyll it enhances metabolic activities of plant (Barker & Bryson, 2007; Hawkesford et al., 2012). Plant uptake nitrogen as nitrate (NO^{3-}) and ammonium (NH^{4+}) form. Compared to ammonium, nitrate is more soluble in soil, making it more accessible to plants and more prone to leaching. (Rennenberg et al., 2009; Miller & Cramer, 2004).

When plants lack nitrogen, their growth is usually inhibited and their leaves become narrow. Chlorosis brought on by N shortage typically begins in the older leaves and spreads to the younger leaves when N is remobilized. In the field, crops lacking nitrogen appear pale green or even yellow (Hawkesford et al., 2012). When tea plants lack nitrogen in the field, their internodes shorten and their young flushes have a lighter green hue than usual. Lower mature leaves may remain dark green and gradually become yellow as the deficit progresses, whereas younger leaves may turn yellow. The deficiency symptoms of nitrogen are presented in figure 2 which was found in Mehedibagh Division of Ghazipore Tea Estate which is located at Kulaura upazila of Moulvibazar district. A lack of nitrogen may result from feeder roots' reduced capacity to absorb nitrogen from the soil during dry spells and cold weather (TRFK, 2002; Hajiboland, 2017).

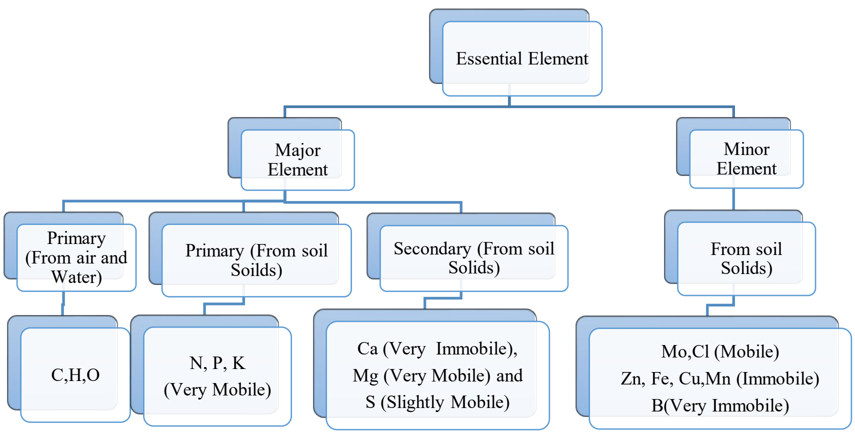


Figure 1. Types of essential elements

Figure 2. Nitrogen deficiency symptoms in tea plants

Figure 3. Phosphorus deficiency symptoms in tea plants

Figure 4. Potassium deficiency symptoms in tea plants

Sana (1989) also stated that, nitrogen deficiency may be somewhat seasonal especially due to waterlogged condition or obstruction by hardpan of soil. In Bangladesh the supply of nitrogen for tea soil through urea is very common phenomena and it's done in two splits depends on yield of the sections of a tea garden. For the favorable yields ranging from 1000 kg/ha to 3000 kg/ha 'made tea' per year the supplement of N by broadcasting method ranging from 110 kg/ha to 348 kg/ha Urea in a year as first split and 132 kg/ha Urea as second split (Kibria & Rashid,1994). Depending on the conditions of a tea field such as deficiency or boost up the yield or to recovery the yield after severe attack of helopeltis, nitrogen may be applied by foliar application (Urea 2 to 4 kg (1 to 2%) each in 200 liter water/ha) and two such application may be given at monthly interval especially September/October or October/November (Motalib & Dutta, 2011).

Phosphorous (P)

Additionally a necessary macronutrient, phosphorus is vital to higher plants' cellular composition and energy metabolism (Hawkesford et al., 2012). Phosphate ion concentrations in soil solutions can be as low as 0.001 (ppm), with in-plant dry weights ranging from 0.1% to 0.5%. Soil P is most accessible for plant growth in the soil pH range of 6.0 to 7.0 (Sharma et al., 2022). In the tea plant, phosphorus is essential for the growth of new wood and roots. Phosphorous encourages root growth of tea plants & cell division as well as being a constituent of ATP and ADP it involves in enzymatic reaction in tea plant cell (Kibria & Rashid, 1994). Khan et al. (2013) found that the critical limit for accessible phosphorus in tea soil is 10 $mgkg^{-1}$. A lack of brightness in tea, particularly in mature leaves, and dieback of both young and old woody stems are indications of phosphorus deficiency (TRFK, 2002). Motalib & Dutta (2011) stated that deficiency symptoms of phosphorous in tea plants are slowing down of the growth, late maturity, dark or grayish young leaves, stems become slender and often woody. The most visible deficiency symptoms of phosphorous in tea plants are smaller leaf and thinner branches. The most important deficiency symptoms of phosphorous in tea plant are dark green color and loss in glossiness of leaf (Kibria & Rashid, 1994; Motalib & Dutta, 2011). Figure 3 depicts phosphorus deficiency symptoms, which are most commonly reported at Bilascherra Experimental Farm in Srimangal and Monipur Tea Estate in Sylhet. Plant vitality is diminished due to a lack of protein production and fewer new rootlets (undeveloped roots). Based on tea output (1000 Kg/ha to 3000 Kg/ha), TSP fertilizer is applied at 44 Kg/ha to 88 kg/ha in tea fields using the broadcasting method during the first fertilizer split. If phosphorous deficiency found in the tea field, DAP fertilizer can be applied at 2% (4kg in 200 liter water/ha.) and two-three such application may be given at month interval (Kibria & Rashid, 1994; Motalib & Dutta, 2011).

Potassium (K)

Potassium is also vital in plant metabolic activities, where enough levels are required for numerous enzymatic reactions such as ATP and ADP (Sharma, 2022). The main source of K for tea plants are organic matter, minerals and chemical fertilizers. Potassium availability is influenced by a variety of parameters, including soil texture, pH, soil depth, and liming material, which explains why K uptake is frequently equal to or greater than nitrogen uptake. The essential limit of accessible potassium in tea soil, according to Khan et al. (2013), is 80 $mgkg^{-1}$. The deficiency symptoms of potassium are resulting in a lack of carbohydrate and hence poor foliage, development of thinner and twiggy wood with poor recovery after plucking and pruning. The most common and visible symptoms are scorching, Marginal necrosis in mature leaves and die-back (Motalib & Dutta, 2011). Figure 4 depicts the potassium deficiency symptoms identified at the Bangladesh Tea Research Institute (BTRI) Farm in Srimangal. Based on the yield of tea, MOP fertilizer is applied at 60 kg/ha to 150 kg/ha in tea field by broadcasting method during first split and 60 kg/ha during second split of fertilizer application to resolved the lacking of potassium (Kibria & Rashid, 1994). . If potassium deficiency found in the tea field, foliar application of MOP fertilizer can be performed at 1% (2kg in 200 liter water/ha.) (Motalib & Dutta, 2011).

Calcium (Ca)

Calcium is a major element and the sources of calcium are organic matter, minerals, and chemical fertilizers and lime (Zohora et al., 2022; Motalib & Dutta, 2011). In higher plants, calcium has a variety of specific roles, including impacts on enzymes, cell walls, and membranes. (Hawkesford et al., 2012). Calcium is necessary for continued growth of apical meristematic cells as well as most important for nitrate reduction in plant tissue (Motalib

& Dutta, 2011). The essential limit of accessible calcium in tea soil, according to Khan et al. (2013), is 90 $mgkg^{-1}$. Similar to potassium concentrations, calcium concentrations in plants range from 1 mgg^{-1} to 50 mgg^{-1} Ca dry matter, with different plant species having different essential calcium concentrations (Pilbeam & Morley, 2007). Plants that are inherently deficient in calcium have a range of diseases that impact their tissues or organs, even while the soil contains an excess of calcium. These diseases are characterized by a broad breakdown of membrane and cell wall integrity brought on by a deficiency of calcium in the tissues, which permits phenolic precursors to enter the cytoplasm. Furthermore, melanin compounds and necrosis are produced by the oxidation of polyphenols inside the impacted tissues. The disintegration of cell walls and membranes frequently results in microbial infection. (Pilbeam & Morley, 2007). In addition the most common and visible deficiency symptoms of Ca in tea plants are tips of plant and tips of top leaves die back, petiole & apical bud collapse with smaller inter-node and terminal bud usually dies. Break down at top and margin at tip (Kibria & Rashid, 1994). The deficiency symptoms of calcium are found in the Ghazipore Tea Estate's Mehdibagh Division in Kulaura, as seen in Figure 5. The shortage of Ca in tea soil can be resolved by applying dolomite depends on soil pH. Aluminium (Al^{3+}) toxicity can be decreased by applying lime or dolomite, which can replace Al^{3+} and H^{+} ions in the root plasma membrane with Ca^{2+} ions (Pilbeam & Morley, 2007).

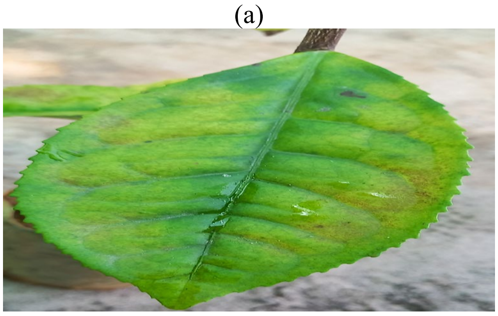
Magnesium (Mg)

As the only mineral component of the chlorophyll molecule that controls photosynthesis and is essential for the successful production of tea, magnesium is the most important nutrient for tea plants (Jayaganesh & Venkatesan, 2010). Furthermore, magnesium activates a wide range of enzymes involved in the metabolism of carbohydrates, nucleic acid production, and sugar translocation. (Kibria & Rashid, 1994). However, the majority of Bangladesh's tea-growing soils have low to medium levels of magnesium availability. The essential limit of accessible magnesium in tea soil, according to Khan et al. (2013), is 25 $mgkg^{-1}$.

On a dry weight basis, harvestable tea shoots have a magnesium content of 0.20% to 0.30%. Since tea is a leaf crop, it needs to be fertilized at high rates in order to yield large amounts of leaves. But each year, high K applications decrease Mg uptake because of the antagonistic relationship between K and Mg, which causes Mg deficiencies in tea plants (Venkatesan, 2006). Mature tea leaves exhibit the earliest signs of a magnesium deficit, which manifest as an inverted “V”-shaped chlorosis and yellow zones on either side of the older leaves' main veins. Eventually, the insufficiency causes the mature leaves to shed (Leaf shading is common and more severe in older leaves) and Necrosis is also common (Palani, 2019). The deficiency symptoms of magnesium are presented in Figure 6 (a, b) were found in a tea estate at Fatikchhari upazila of Chattogram district and Bilashcherra Experimental Farm, Srimangal. If magnesium deficiency found in the tea field, two times foliar application of 1% to 2% Magnesium Sulphate (2kg to 4 kg in 200 liter water/ha) can be performed at month interval (Motalib & Dutta, 2011).

Figure 5. Calcium deficiency symptoms in tea plants

(a)



(b)

Figure 6 (a, b). Mg deficiency symptoms in tea plants

Sulphur (S)

In addition to being nutrition, sulfur acts as a fungicide on tea plants. Sulphur-based compounds in various formulations were shown to be highly beneficial in preventing tea mite pests. As a result, in integrated nutrition and pest management strategies for tea cultivation, sulfur fertilizers have been suggested (Ahmed et al., 2011). Though, there is a various sources of sulphur unlike soil such as organic matter and manure, minerals, chemical fertilizers, although in some circumstances, there are some lacking of sulphur observed in tea plants (Motalib & Dutta 2011). Sulphur has some distinct function in tea plant. It is necessary for formation of certain proteins and for cell division and plays a unique role in plant metabolism as well as assists the plant in the production of chlorophyll and increase root systems. It helps in proteins synthesis and chlorophyll formation (Gunaratne et al., 2008).

A sulfur deficit is characterized by a widespread yellowing of the leaves and a loss in leaf size; younger leaves are usually affected before older ones. Motalib & Dutta (2011) stated the yellowing of young leaves of tea in the early stage of sulphur deficiency, with severe deficiency even the older leaves become pale green or bright yellow and may cause tea- yellows. The veins of the tea leaves become lighter green than the rest of the leaves with narrow leaves due to sulphur deficiency. Figure 7 displays the symptoms of sulfur deficiency that were discovered at the Bangladesh Tea Research Institute (BTRI) plantation in Srimangal. If the deficiency is not addressed over an extended length of time, the yellowed leaves will eventually develop necrosis at the tips and margins, followed by defoliation. Foliar application of 1% Zinc Sulphate 1% to 2% Magnesium Sulphate can correct a sulfur deficiency (Motalib & Dutta 2011).

Figure 7. Sulphur deficiency symptoms in tea plants

Minor Element

Zinc (Zn)

The metabolic functions of zinc are the formation of growth hormones, promotes protein synthesis and enhance seed maturation and production. Severe zinc deficiency causes a significant death rate in tea plants as well as restricted growth; immature leaves become narrow, upright, distort, and curl apical buds, forming a rosette at the tip of the stem with sickle leaves that are unevenly sized and formed (Kibria & Rashid, 1994; Nelson, 2006; Motalib & Dutta, 2011). Figure 8(b) shows the zinc deficiency symptoms that were discovered in Sabari Tea Estate, and Bilashcherra Experimental Farm in srimangal. Since zinc is not readily absorbed by tea plants, foliar spray is the most efficient way to address a zinc deficiency; soil application is not recommended. Zinc application raises the yield of produced tea by increasing the amount of chlorophyll, the net photosynthesis rate, and the efficiency of water consumption (Hajiboland, 2017). During severity of zinc deficiency in the tea plants, foliar application of 1% Zinc Sulphate is the most effective way to correct the deficiency (Motalib & Dutta, 2011).

(a)

(b)

Figure 8 (a, b). Zinc deficiency symptoms in tea plants (Figure a is adapted from Nelson, 2006 and figure b was found in Bilashcherra Experimental Fam)

Boron (B)

Boron has a vital part in cell division, protein synthesis, nitrogen and carbohydrate metabolism, root system growth, reduces the rate of water absorption and sugar transfer, and is responsible for apical failure when inadequate (Zoysa, 2008; Kibria & Rashid, 1994). The supply of boron from soil to tea plants is quite low, making it one of the elements in tea plants that are the most immobile (McCauley et al., 2009). With the aging of tea, it was discovered that the amount of boron in the soil decreased (Hajiboland, 2018). In tea plant boron deficient create formation of cork mound on the leaf stalk (Muraleedharan et al., 2007), tip burning, and die back from the top is the most visible deficiency symptoms of boron deficiency. The deficiency symptoms of boron are presented in Figure 9. In addition leaves may become narrow, twisted, leathery and dark green in color due to boron deficiency in tea soil (Motalib & Dutta, 2011). If boron deficit occurs in the tea field, two foliar applications of 1% boron fertilizer at monthly intervals may be administered.

Figure 9. Boron deficiency symptoms in tea plants (adapted from Zoysa, 2008)

Copper (Cu)

Copper, a redox-active transition element, plays a role in respiration, carbon and nitrogen metabolism, photosynthesis (the production of chlorophyll), and oxidative stress resistance. Enzymatically bound copper, which catalyzes redox processes and aids in the metabolism of proteins and carbohydrates, accounts for the majority of the functions of copper as a nutrient for plants (Motalib & Dutta, 2011). The authors also revealed that copper nutritional status is likely to have a significant impact on the quality of green and black tea, as it increases fermentation duration.

The copper deficiency in tea plants are very distinct as slightly darker leaves with becoming dark brown rather than bright orange, weepy buds and plants are more prone to fungal diseases. Figure 10 depicts the copper deficiency symptoms discovered at Marina Tea Estate, Kulaura, Bangladesh Tea Research Institute (BTRI) Farm, Srimangal and Oodaleah Tea Estate, Chittagong. In Bangladesh, copper fungicides are used in tea gardens immediately after pruning to protect tea plants from fungal infection, which may play a significant role in correcting copper deficiencies in tea plants. (Motalib & Dutta, 2011).

Manganese (Mn)

Manganese has taken part as a constituent of chlorophyll and assimilated CO_2 during photosynthesis and breakdown carbohydrate. It has also various functions in enzymatic reactions, phosphorous translocation in tea plants as well as takes part in nitrogen and inorganic acid metabolism and helps in the formation of carotenes, riboflavin and ascorbic acid (Kibria & Rashid, 1994; Motalib & Dutta, 2011).

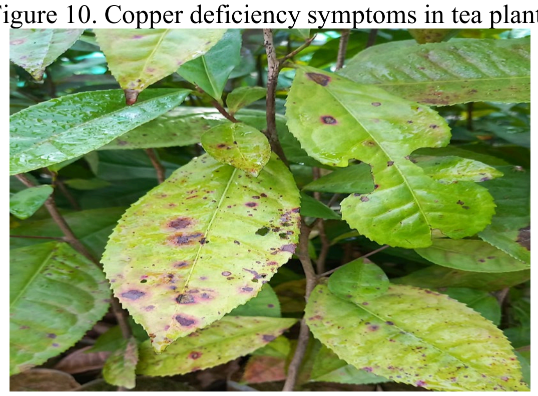
Manganese shortage is common in soils generated from manganese-poor parent material, as well as in extensively leached tropical soils. On the other hand, the amount of exchangeable manganese (mostly Mn^{2+}) in the soil solution was growing in acidic soils. One important strategy for reducing soluble manganese in acidic soils is the application of lime or dolomite (Hajiboland, 2018). The most visible Manganese deficiencies are marginal and interveinal chlorosis in mature and lower leaves, chlorotic and necrotic spots interveinal region of leaves with molted of red brown spots (Grey Speck disease) as well as number of green veins reduced (Kibria & Rashid, 1994; Motalib & Dutta, 2011). The manganese deficiency symptoms shown in Figure 11 were discovered at the Monipur Tea Estate in Sylhet; Ghazipore Tea Estate in Kulaura; and Bilashcherra Experimental Farm in Srimangal. During the survey manganese deficiency was found in the secondary nursery plants which age was above 1.5 years which might be due to low manganese content in the soil. Manganese deficiency can be corrected by the 1 to 2 time's foliar application of 1% manganese sulphate at monthly interval (Motalib & Dutta, 2011).

Chemical Analysis of Tea Leaf

The chemical analysis results of the collected tea leaf samples from different tea estates are given in the table 1 (Average values are used).

The leaf samples of the Mazdehee tea estate had the highest mean nitrogen content (5.18%), whereas the leaf samples of the Monipur tea estate had the lowest mean nitrogen content (2.95%) (Table 1). Significant variations ($^{ANOVA}F = 40.24$, $p < 0.001$) were observed in the content of nitrogen in tea leaf samples among the different tea estates (Figure 12). The tea leaf samples of Mazdehee tea estate had wider variability in their nitrogen contents (Figure 12). It was discovered that the average nitrogen content of the tea leaves in the Mazdehee tea plantation differed considerably from that of other tea gardens. In the tea leaf samples from Saif, Monipur, and Marina tea estates, there was no discernible variation in the mean nitrogen level (Figure 12). According to Owuor (1997), a tea plant is nitrogen deficient if its total leaf nitrogen concentration is less than 3%, slightly deficient if it is between 3.0% to 3.5% and sufficient condition if it is greater than 3.5%. As a result of the analysis of the gathered samples, it was discovered that tea leaf samples from the Monipur and Marina tea estates were nitrogen deficient, and the nitrogen content of the tea leaves from the Saif tea estate was slightly deficient. The nitrogen concentration of the tea leaves from Mazdehee tea estate was found to be sufficient.

Figure 10. Copper deficiency symptoms in tea plants



(a)

(b)

Figure 11 (a, b). Manganese deficiency symptoms in tea plants

Table 1. Chemical analysis of the tea leaves

Name of the Tea Estates	Total N (%)	Total P (%)	Total K (%)	Total Ca (%)	Total Mg (%)	Total Zn (%)
Marina	$2.97^{b} \pm 0.03$	$0.43^{a} \pm 0.05$	$1.72^{a} \pm 0.18$	$0.18^{b} \pm 0.03$	0.08 ± 0.008	0.003 ± 0.001
Mazdehee	$5.18^{a} \pm 0.88$	$0.28^{b} \pm 0.07$	$0.56^{b} \pm 0.15$	$0.49^{a} \pm 0.23$	0.08 ± 0.02	0.002 ± 0.001
Monipur	$2.95^{b} \pm 0.17$	$0.44^{a} \pm 0.06$	$1.88^{a} \pm 0.13$	$0.17^{b} \pm 0.03$	0.08 ± 0.01	0.004 ± 0.001
Saif	$3.07^{b} \pm 0.14$	$0.49^{a} \pm 0.06$	$1.68^{a} \pm 0.28$	$0.12^{b} \pm 0.06$	0.07 ± 0.007	0.003 ± 0.002

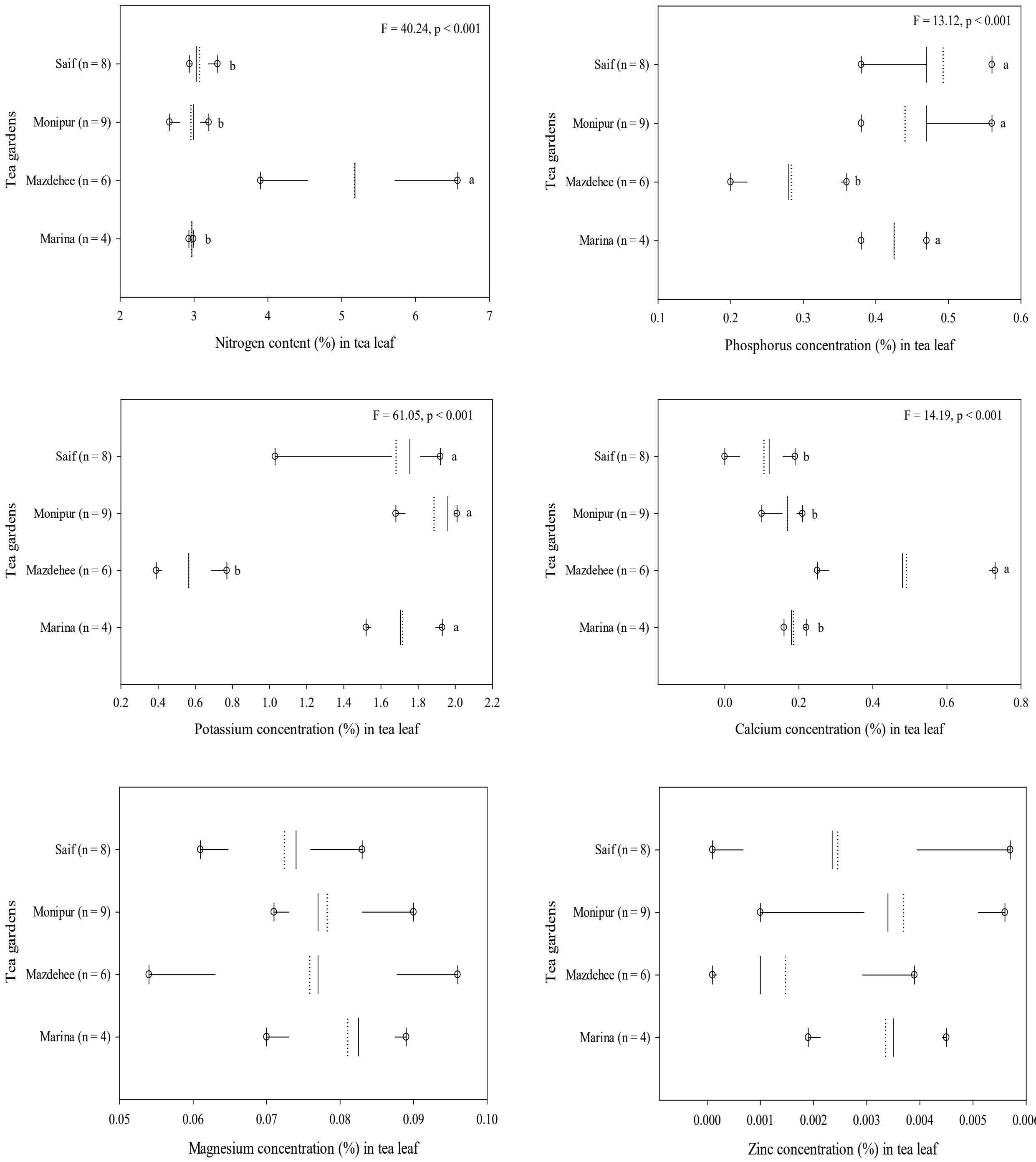


Figure 12: The nitrogen, phosphorus, potassium, calcium, magnesium, and zinc concentrations (%) in the tea leaves of various tea gardens are displayed in box and whisker plots. Sample numbers are indicated by figures in parenthesis. The box plots display the median (solid line), the lower and upper quartiles (box), the 5th and 95th percentiles (circles), and the 10th and 90th percentiles (whiskers). An analysis of variance (ANOVA) test yielded the F-value and P-value. The F-value and P-value stand for the F-ratio, which shows how much variance there is among the tea gardens and how significant that variation is, respectively. The grouping for the tea gardens obtained using one-way ANOVA to distinguish pair-wise the mean of each tea garden is indicated by the Tukey letters a, b. There aren't many notable differences between the tea estates that have the same letters.

The highest mean content of Phosphorous (0.49%) was discovered in the leaf samples of Saif tea estate and the lowest mean content of phosphorous (0.28%) was found in the leaf samples of Mazdehee tea estate (Table 1). Significant variations ($^{ANOVA}F = 13.12$, $p < 0.001$) were observed in the content of phosphorous in tea leaf samples among the different tea estates (Figure 12). The tea leaf samples of Saif tea estate had wider variability in their phosphorous contents (Figure 12).

Compared to other tea gardens, the mean phosphorus content of the tea leaves of the Mazdehee tea estate was found to be significantly different. The mean amount of phosphorus in the tea leaf samples from the Saif, Monipur, and Marina tea estates was not significantly different (Figure 12). Same result was shown by Chen & Lin (2016) where phosphorus contents in tea leaves are 0.25% to 0.4%. During this research phosphorous deficiency of collected tea leaves were not found. Regarding this issue Hamid (2006) stated that under moderate soil pH conditions, roughly 5.5 to 7.0, tea plants have a good Phosphorous availability; however, Phosphorous availability may be reduced at pH values below 5.5 or over 7.0. Phosphorous is adsorbed onto the hydroxides of Fe and Al in extremely acidic soils, rendering it inaccessible to plants. The formation of roots is necessary for P absorption since the phosphate ion is immobile (Neumann & Römheld, 2012). Therefore, the analytical results of the collected leaf samples represent sufficiently supplement of phosphorous in tea leaf.

The leaf samples from the Monipur tea estate had the highest mean potassium content (1.88%), whereas the leaf samples from the Mazdehee tea estate had the lowest mean potassium content (0.56%) (Table 1). Significant variations ($^{ANOVA}F = 61.05$, $p < 0.001$) were observed in the content of potassium in tea leaf samples among the different tea estates (Figure 12). The tea leaf samples of Saif tea estate had wider variability in their potassium contents (Figure 12). Compared to other tea gardens, the mean potassium content of the tea leaves of the Mazdehee tea estate was found to be significantly different. In the tea leaf samples from Saif, Monipur, and Marina tea estates, there was no discernible variation in the average potassium level (Figure 12), however the tea leaves from Mazdehee tea estate showed a deficiency in potassium. The potassium levels of tea leaves were found to be 1.5% to 2.1% and 1.46% to 2.68% respectively, in similar types of studies (Chen & Lin, 2016; Adiloğlu & Adiloğlu, 2006).

The highest mean content of Calcium (0.49 %) was discovered in the leaf samples of the tea estate Mazdehee and the lowest mean content of Calcium (0.12 %) was found in the leaf samples of Saif tea estate (Table 1). Significant variations ($^{ANOVA}F = 14.19$, $p < 0.001$) were observed in the content of Calcium in tea leaf samples among the different tea estates (Figure 12). The tea leaf samples of all estate had smaller variability in their calcium contents (Figure 12). The mean calcium content of tea leaves from the Mazdehee tea plantation differed significantly from that of other tea gardens. The mean potassium level in tea leaf samples from the Saif, Monipur, and Marina tea estates did not differ significantly (Figure 12). Carr et al. (2003) estimated that among essential elements, young tea leaves contain on average 3560 $mgkg^{-1}$ (0.36%) Ca while old leaves contain on average 18,700 $mgkg^{-1}$ (1.87%) calcium. Adiloğlu & Adiloğlu (2006) found in another study that the calcium content of tea leaf samples ranged from 0.33% to 0.86%. It may be inferred from Table 01 and the results of the aforementioned studies that the leaf samples from the Marina, Monipur, and Saif tea estates are calcium deficient.

The highest mean content of Magnesium (0.08%) was found in the leaf samples of Mazdehee, Marina and Monipur tea estate and the lowest mean content of Magnesium (0.07%) was found in the leaf samples of Saif tea estate (Table 1). No discernible variations were found in the magnesium concentration of tea leaf samples from the various tea plantations (Figure 12). The tea leaf samples of Mazdehee, Monipur and Saif tea estate had wider variability in their Magnesium contents (Figure 12). According to the findings of Adiloğlu & Adiloğlu (2006) and Carr et al. (2003) where Mg content of tea leaves was 0.15% to 0.38% and 0.17% (young leaf) to 0.26% (old leaf) respectively; it can be evaluated that the Magnesium content of the collected leaf samples of these four tea estate (table.01) were deficient.

The leaf samples from the Monipur tea estate had the greatest mean zinc content (0.004%), whereas the leaf samples from the Mazdehee tea estate had the lowest mean zinc content (0.002%) (Table 1). There are no discernible variations in the zinc concentration of tea leaf samples between the various tea estates (Figure 12). The zinc contents of the tea leaf samples from the Mazdehee, Monipur, and Saif tea estates varied more widely (Figure 12). According to Özyazıcı et al. (2011) Zn contents of leaf samples were determined as 5.6 $mgkg^{-1}$ to 46.3 $mgkg^{-1}$ (0.0006% to 0.005%) and same research was done by by Adiloğlu & Adiloğlu (2006) where Zn content was 30 $mgkg^{-1}$ to 56 $mgkg^{-1}$ (0.003% to 0.006%). On the basis of the above findings our results of Zn content were determined sufficient (0.002% to 0.004%). Tea plants thrive in acidic soil, resulting in high Zn solubility (Adiloğlu & Adiloğlu 2006). As a result, zinc deficiency is rare in Bangladeshi tea plantations.

Conclusion

Tea is a monoculture crop that requires particular soil and environmental circumstances for optimal cultivation, such as heavy rainfall, high humidity, and acidic soil. Large volumes of fertilizer are required to obtain a high tea yield in tea-growing countries like Bangladesh due to global environmental changes like lower rainfall and/or inadequate distribution throughout the year. But when soil faces the lack of a specific nutritional component then it shows their deficiency symptoms in the plants. In essence, nutrient shortages lead to a decline in crop health and productivity and can also cause odd visual symptoms to manifest. By comprehending the function and mobility of each vital nutrient in the plant, one can determine which nutrient is accountable for a deficient symptom. Growth retardation, chlorosis, interveinal chlorosis, purple or red discoloration, and necrosis are examples of general deficiency signs. Older, lower leaves are the first to show signs of mobile nutrient shortages, while younger, upper leaves will show signs of static nutrient deficiencies. In order to confirm nutrient stress, soil or plant testing is necessary. Mostly, visual observation serves as a diagnostic tool, but it might be limited by a number of factors, such as hidden hunger and false deficiencies. Based on the results of this survey study tea fresh leaf samples are analyzed where Nitrogen, Potassium, Calcium and Magnesium deficiency was determined which was correlated with collected photographs of deficiency symptoms in tea plants. However, assessing visual deficiency symptoms in the field is a quick and low-cost way to find possible nutrient deficiencies in tea plants. It is important to learn how to recognize symptoms and their causes in order to manage and solve issues with soil fertility and crop production, so this skill should be used effectively.

Declarations

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