EVALUATION OF SOIL FERTILITY STATUS AND NITROGEN FERTILIZER ON TEA (C. sinensis L.) YIELDS IN TANGA REGION, TANZANIA

BY

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A THESIS SUBMITTED TO THE SCHOOL OF AGRICULTURE AND BIOTECHNOLOGY, UNIVERSITY OF ELDORET, IN PARTIAL FULFILLMENT FOR THE AWARD OF A MASTER OF PHILOSOPHY DEGREE IN SOIL SCIENCE, DEPARTMENT OF SOIL SCIENCE

SCHOOL OF AGRICULTURE AND BIOTECHNOLOGY

UNIVERSITY OF ELDORET, KENYA

OCTOBER, 2013

DECLARATION

Declaration by student

I declare that this thesis is my original work and has not been presented for examination in any other university. No part of it may be reproduced without prior written permission from the author and / or University of Eldoret.

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DEDICATION

This thesis is dedicated to my family: My father and mother, my wife, my children, all my brothers and sisters for their support, prayers and kindness which allowed me to fulfill my academic Ambitions

ABSTRACT

Tea yields in Lushoto district, Usambara mountain northeast Tanzania have been declining over the years, affecting economic development of the district and the country at large. The decline has been attributed to among others, poor soil conditions. The objective of this study was therefore to identify the soil related causes of yield decline and suggest/provide corrective measures towards improvement of yields in small holder farmers' fields. The study was first carried out through a survey, conducted on smallholder tea farms to gather information from farmers on nutrient diagnosis. Thereafter soil and plant tissue samples were collected for analysis to determine whether the present low tea yields are related to the status of soil fertility on the farms. Soil and plant tissue samples collected from different smallholder tea farms in the district were subjected to chemical and physical analysis – (i) soil: pH, total N, available P, K, Ca, Mg, S, EC, CEC, %OC, Al, Cu, Zn, Fe, Mn and texture (ii) plant tissue: N, P, K, Ca, Mg, S, Cu, Zn, Fe and Mn. The resultant data was statistically analysed and overall mean values checked against the Tea Research Institute of Tanzania (TRIT)'s set critical levels required for optimum tea yield. Nitrogen in soil and plant tissue macronutrient analytical results from the farms was below the critical set values also Phosphorus and Potassium in soil were below the critical values. Copper in soil and plant tissue micronutrient analytical results from the farms was below the critical set values. A field experiment was then set up as a second study to determine plant responses to fertilizer application Urea, Triple super phosphate and Muriate of potash. The experiment was a Randomized Complete Block Design (RCBD) replicated three times, laid out in a 4 x 8 factorial arrangement. The treatments consisted of four clones (K 7, K 35, 282 and 207) and eight nitrogen fertilizer levels (0, 40, 80, 120, 160, 200, 240, 280 kg N ha^{-1}). During the short rain season: clones K 35, K 5 and 282 at N application of 160 kg N/ha yielded the best. In the long rain season; clone 207 at N rate of 120 kg N/ha yielded the best. Annual mean yield indicates that two clones were superior; K 35 and 282 together with N application rates at 120 – 160 kg N/ha. It was concluded from the study farmers' field in four schemes were identified that the most limiting nutrient. On top of the list is nitrogen followed closely by phosphorus potassium and copper.

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LIST OF ABBREVIATIONS

AEZs	The Agro-ecological zones
Al	Aluminum
ANOVA	Analysis of variance
Bo	Boron
Ca	Calcium
CEC	Cation Exchange Capacity
Cu	Copper
EC	Electrical conductivity
EUTCo	East Usambara Tea Company
FAO	Food and Agricultural Organization
Fe	Iron
GEF	Global Environmental Facility
GDP	Gross Domestic Product
H	Hydrogen
IPPTSS	Investment and Profitability Potential in Tea Sub-Sector.
K	Potassium
kg	Kilogram
LSD	Least Significant Difference
Mg	Magnesium
Mn	Manganese
MTE	Mponde Tea Estates
MTRS	Marikitanda Tea Research Station (MTRS)
Na	Sodium
N	Nitrogen

NH_4^+	Ammonium
No_3^-	Nitrate
OC	Organic carbon
TTA	Tanzania Tea Authority
TBT	Tea Board of Tanzania
TRIT	Tea Research Institute of Tanzania
TSHTDA	Tanzania Smallholders Tea Development Agency

ACKNOWLEDGEMENT

First and fore most, I would like to thank for Prof. C. Othieno and Prof. W. Ng'etich from the Department of Soil Science, University of Eldoret, Kenya, my supervisors who proved their devotion to the successful completion on this research for their courage, guidance and comments.

I would also like to extend my thanks to the management of Tea Research Institute of Tanzania (TRIT) for giving me this opportunity to carry out the study. My special thanks is also to, Dr. Simbua and Dr. Kimambo for their support in conducting this study.

My special thanks is to the Ministry of Agriculture, Food Security and Cooperatives, Tanzania for funding this research is highly acknowledged. The encouragement and assistance I received from the Director of Research and Training Development Dr. Myaka and the former Director Agriculture Research Institute ARI-Uyole, Mbeya Dr. Mrs C Madata.

Last but not least, my special thanks and sincere appreciation goes to my wife Mpoki Jimson who not tired from the heavy burden of caring for our sons Daniel and Joshua and daughter Gladness, enabling me to devote time to work on this study and also for her understanding.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Tea (*camellia sinensis.* L) is a beverage cash crop whose tender succulent shoot of two leaves and a bud constitute the economic yield (Wilson, 1969; Othieno,1992). Worldwide, tea is grown in subtropical and tropical areas. Tea originated from China around 2750 BC, and was introduced in Tanzania by the German settlers at Agricultural Research Station Amani, Tanga 1902. It was first planted at Kyimbila in Rungwe District, Mbeya region in 1904. The Smallholder tea farming began during the 1960s. In 1968, the government initiated a full-fledged smallholder tea development program. The estate and smallholder's trend of production and yields of made tea in Tanzania for the years 1975/76–1999/2000 and 2006/07−2009/I0 is as shown in appendix VI (TBT, 1910). The tea sector in Tanzania is of economic importance, providing annual foreign exchange revenue of over 30 million US$ after coffee, cotton and tobacco. In Tanzania, the agricultural sector contributes approximately 50 per cent of total Gross Domestic Product and contributes over 60 per cent of export earnings, mainly in the form of cash crops. Over 70 per cent of the population lives in the rural areas where agriculture and related non-farm activities are their main occupation. It also accounts for 80 per cent of the income and employment opportunities for many livelihoods, especially in the rural area. (Keenja, 2004).

Soil fertility is not a static feature, it changes constantly in two directions; depletion or restoration determined with interplay between physical, chemical and biological processes, The major primary nutrients required by tea are nitrogen, phosphorus, potassium and sulphur (Othieno, 1992). Increasing soil-nutrient depletion through leaf harvests causes lack of nutrients in tea plants as a result crop yield declines N, P are the major essential nutrients, which are depleted at faster rate than other nutrients such as K, S, Ca, Mg and micronutrients. It is possible that after long term cultivation other nutrients in addition to NPK if not replenishment may be depleted to the extent of limiting tea yields.. Application of compound fertilizers such as NPK 5:1:1, NPKS 25:5:5:5 or mixing of straight fertilizer such as Urea (46%N) and sulphate of Ammonia (21%,N), TSP (46% P_2O_5), Murate of potash (60% KCl)sulphate of potash (50% K2SO4) These fertilizers used to replenish nutrients removed or lost through harvesting of the tender shoots or by other ways in order to have sustainable production of quality young harvestable tender shoots all the year round (Anon, 2002).

According to farming systems survey conducted in Lushoto, Muheza and Korogwe districts of Tanga region in order to identify constraints, opportunities and areas for intervention in smallholder tea production The survey also aimed at collecting information that assist TRIT to set priorities for research and development in tea based smallholders' farming systems (TRIT, 1999). Some identify constraints on soil fertility depletion such as for several years' smallholders have been using fertilizers in their tea fields, but farmers are still not conversant with the types, names of these fertilizers, farmers are likely to face difficulties in determining the fertilizers suitable for their fields. Another issue is that most of the farmers allocating tea inputs to other crops, some farmers even sold Supplied fertilizers to other farmers these may leading to differences in soil fertility depletion among farms(TRIT, 1999). However, other factors were found to contribute to the accelerated soil fertility depletion such as poor farmer's practices, improper soil conservation measures especially in young tea farms and poor fertilizer management. To sustain agricultural productivity over a long period of time effective resource management practices including sound soil nutrient management are important agricultural practices for farmers, not only to increase soil nutrient concentrations but also to improve the structure of the soil, and reduce soil losses through erosion.

The purpose of this study it was to evaluate the present soil fertility status and fertilizer use on tea yields and test a nitrogen fertilizer response to in farmers` tea fields

1.2 Statement of the problem

Low tea production persists in the farms in the Lushoto district in Usambara Mountains. It has been observed that some farmers get very low annual yields of between 770−1760 kg made tea/ha/year compared to current yield obtained in well managed farms of 3000 – 3500 kg made tea/ha/year in some parts of Tanzania (TRIT, 1999; TSHTDA, 2010; Priest, 2010). This state of affairs is probably due to low/ depleted soil fertility. In Lushoto district little has been done to evaluate the impact of soil fertility status on tea yields. Apart from low soil fertility, there might be other factors that most likely contribute to low tea yield in smallholder's farms and affect tea production. Some of these factors include poor management in most smallholder tea farms such as inadequate use of inputs; no application of fertilizer for up to 10 years, poor weeding, numerous gaps in tea stands, poor plucking, lack of a reliable source of planting materials and failure to adopt new clone varieties from research. Also there are other factors which indirectly contribute to soil fertility depletion, such as farmers having low income generated from tea, which oftentimes is payed late. These tend to affect farmers who can be easily discouraged and switch production systems, neglecting tea production.

1.3 Justification

Tea is the fourth largest export crop in Tanzania with over US$ 30 million in export earnings, over 31,253 farmers are directly engaged in tea production and while many more are engaged indirectly (Emukule, 2008). More than 50% of acreage in Tanzania is owned by smallholder tea farmers, but the farmers produce only 24% of the annual tea produced in Tanzania (TSHTDA, 2010), this being attributed to low soil fertility. Therefore there is need to evaluate present soil fertility status in relation to present yields in the smallholder sector of Lushoto district. This wills promote tea production, quality tea and processing, higher revenue/income gains by farmers.

1.4 Research objectives

1.4.1 General objective

To determine present soil fertility status (chemical and physical properties) and response to nitrogen fertilizer on yields of tea in Tanga region, Tanzania

1.4.2 The specific objective

I. To determine the soil physical and chemical characteristics and leaf nutrient contents in smallholder farms in Lushoto district.

III. To determines the yield response of four commercial tea clones on Nitrogen fertilizer at Marikitanda Tea Research Station.

1.5 Hypothesis

Ho: There are no effects in the soil physical and chemical characteristics and leaf nutrient contents on yield in smallholder farms in Lushoto district.

Ha: There are effects in the soil physical and chemical characteristics and leaf nutrient contents on yield in smallholder farms in Lushoto district.

Ho: There are no differences on yield of four commercial tea clones when different rates of Nitrogen fertilizer applied at Marikitanda Tea Research Station.

Ha: There are differences on yield of four commercial tea clones when different rates of Nitrogen fertilizer applied at Marikitanda Tea Research Station.

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil nutrients depletion

Pieri, (1989); Stoorvogel and Smaling, (1990) and Van der Pol, (1992) reported that increasing soil-nutrient depletion and crop yield declines is a phenomenon in many farming systems in rain-fed sub-Saharan Africa. Decline in soil fertility due to long term cultivation with little or no fertilizer additions is the major form of land degradation in most sub-Saharan Africa (SSA). The rate of annual soil macronutrient depletion in Africa was estimated at 22 kg N ha^{-1}, 2.5 kg P ha^{-1} and 15 kg K ha^{-1} over 30 years of non-use or insufficient use of fertilizers (Sanchez *et al.*, 2002). In Kisii, Kenya soil depletion was found to be 112 kg N ha^{-1}, 2.5 kg P ha^{-1}, and 70 kg K ha^{-1} (Smaling *et al*., 1993). In smallholder farms nutrient outputs/loss is in numerous ways: harvested products, crop residue removals, leaching, gaseous losses, surface runoff, and erosion (Stoorvogel and Smaling, 1990). Also cultivation of low-potential areas primarily in sub humid and semiarid areas, where many of the sandy soils are naturally infertile contribute to the decline. Still, the smaller soil nutrient stock is also being depleted in these areas (Pieri, 1989; Smaling *et al.*, 1993). Because the soil resource has not kept its productive capability over time, farmers have witnessed low and declining yields. Current crop yields are low due to soil-fertility depletion, poor agronomic practices, droughts, weed and pest attacks and lack of cash for investment. Most smallholder farmers in Africa appreciate the value of fertilizers, but they are seldom able to apply them at the recommended rates and at the appropriate time because of high cost, lack of credit, delivery delays, and low and variable returns (Heisey and Mwangi, 1996).

2.2 Challenges of smallholder tea growers in Tanzania

Tea is grown commercially on soils occupying volcanic minerals (Anon, 1989) these soils are acidic in nature. Old sedimentary soils derived from archaic rocks such as gneiss and granite are good soils for tea production in many areas of world like India, china, Indonesia, Kenya and some parts of Tanzania (Eden, 1952)

Priest, (2010) reports that there were decline in yields of tea in smallholder tea growers in Lushoto, Usambara Mountain and the decline was attributed to soil nutrients depletion. Decline in yield estimates ranged from 550 to 1100 kg made tea /ha /year, in 2006/7, 2007/8 and 2008/9. It was found during the Farming system survey that the main reasons for low productivity were due to poor management. Assessment on use of inputs revealed that most of the farmers apply fertilizer below the rate recommended by TTA of 150 kg N ha^{-1} and some field do not receive fertilizer for 10 years. Another shortcoming was low plant densities, poor weed control, sub-optimal or non-use of fertilizer, poor plucking and pruning strategies. (TRIT, 1999)

2.3 Availability of macro nutrient elements in soils

Nitrogen, phosphorus and potassium are the major nutrients considered as not always in adequate supply in soil to sustain high yields in tea plantation, therefore application of these nutrients in form of fertilizers is recommended (Kamau *et al.,* 1998). Macronutrient elements, indeed the two most widespread limiting nutrients to food production in sub-Saharan Africa are N and P, in that order (Bekunda *et al.,* 1997). For example, in a series of fertilizer trials conducted throughout the Kenyan highlands, N and P deficiencies were reported in 57 and 26% of the cases, respectively (KARI, 1994). K, Ca, Mg, S, and micronutrient deficiencies and Al toxicity do occur in specific circumstances in sub-Saharan Africa, but not to the extent of N and P deficiencies. P deficiencies are probably due to the fixed P on Fe and Al oxides, hydroxides at the surface of layer-silicate clay particles (Smaling *et al.,* 1997). However, crop responses to K fertilization are rare in sub-Saharan Africa, except in sandy savanna soils (Ssali and Keya, 1986). This is probably due to the high K content in many other parts of Africa and the low demands for K due to the current low crop yield levels.

Fertilization with high N quantities decreased the concentrations of Al and other elements (Ca, K, Mg, Mn and P) in young shoots and mature leaves of tea. However, the mechanism for reduced concretion Al is apparently different from those for the other elements. While reduced absorptions of other elements could be explained by their lower availabilities in the soil, the contents of extractable Al actually increased with the application of N fertilizer (Ruan *et al*, 2000). Owuor and Cheruivot (1989) observed that in old tea field experiment, which explained in terms of the inhibitory effect of competition with NH_4^+ during root absorption the concentration of Al in the roots and leaves decreased constantly with the progressively increasing supply of NH_4^+. On the other hand the concentrations of Al and Ca, Mg, Mn in young shoots did increase when low levels of N fertilizer was applied (100 kg N ha^{-1} $year^{-1}$) which was be attributable to improved root growth.

2.4 Nitrogen availability in soils and tea plants

The dynamic nature of N cycling dictates that soil N useful for supplying N for plant growth. Of all nutrients N is required in the greatest quantity for plant growth. Whereas the three principal sources of N for crop production; Biological N_2 fixation. Organic resources recycled within the cropping field or concentrated from a larger area and mineral N fertilizers. The major forms of mineral N in soil are NH_4^+ and No_3^- , (No_2^- is present only as a transient intermediate in nitrification). (Nommik and Vahtras, 1982).

The diversity of soils in the tropics is just as wide as that found at greater latitudes (Eswaran *et al.*, 1992); The amounts of organic C and N stored in West African soils depended on the amount of clay and fine silt-sized particles present, and this is shown for a wide range of African soils (Feller *et al*., 1991). In many acid tropical in soils, notably the Oxisols and Ultisols, USA the clay-size fraction consists mainly of iron (Fe) and Al oxides and in Andisols mainly of allophone affect amounts of organic C and N stored in soils (Amato and Ladd, 1992).

In parts of the world where tea is grown, for example, China N application range from 0 - 2600 kg N /ha with average of 553 kg N /ha annually in typical tea fields (Han and Li, 2002). However, large quantity of N fertilizer application causes low use efficiency resulting in serious environmental pollution. Kiml *et al.,* (2002) reported that in a tea field with N application of 9000 kg N /ha, the N loss via nitrate leaching during the same year was 457 kg N/ha. The $No_3^{□}$ concentration in spring water near tea garden was often around 50 mg/kg. In Japan the N_20 production in 1% of tea lands accounted for 99% of total N_20 produced in all agricultural lands (Nakasone *et al,* 2003). In Kenya Wanyoko *et al.*, (1992); Kamau and Wanyoko (2005) indicated that increasing rates of nitrogen decreased uptake of base nutrients (potassium, calcium, magnesium). Iron, manganese and aluminium are raised in soil solution resulting in lower soil pH and many cause nutrient imbalances. On the other hand, In the Usambara tea growing areas tea yields (clone 6/8) increased linearly from 2170 to 3660 Kg/ made tea/ha/yr as N fertilizer application rates were gradually raised from 75 to 300 kg N/ha (Kigalu *et al*, 2001).   It is estimated that harvestable crop contains between 3.5 and 5.0% N on dry matter basis. This is equivalent to annual removal of between 70 and 100 kg N/ha for low yield tea of 2000 kg made tea ha^{-1}. The annual removal is between 175 and 250 kg Nha^{-1}.

Cordingley (2010) Report that Soil nitrogen levels analyzed across top soil samples in Lushoto district. The levels of soil nitrogen vary from low to high it means range from 0.1 to

0.25. The average soil nitrogen level was 0.71. In third leaf Nitrogen levels was 1.0 – 3.5% in the range of (the critical is 2.2% of leaf nitrogen level), although Landon (1991), categorized total N in soils as very low (<0.1%), low (0.1- 0.2%), medium (0.21- 0.50%) and >0.5% as high.

2.5 Phosphorus availability in soils and tea plants

Phosphorus dynamics in soils are complex, because they involve both chemical and biological processes and the long-term effects of sorption (fixation) and desorption (release) processes. The low concentration and low solubility of P in soils frequently make P a limiting factor. Phosphorus deficiency is widely considered the main biophysical constraint to food production in large areas of farmland in sub humid and semiarid sub-Saharan Africa (Bationo *et al*., 1986). Factors affecting uptake of P include the abilities of plants (plant roots); to absorb P from low soil solution concentrations, to explore a large soil volume, to solubilization soil P through pH changes by release of chelating agents and phosphatase enzymes (Lajtha and Harrison, 1995). Plants differ greatly in their ability to grow on soils with low P status and to respond to P inputs (Sanchez and Salinas, 1981). In tea plantations the availability of soil P can be increased by organic acids and acid phosphatases exuded by plant roots (Delhaize, 1995). Plant induced changes in soil Ph also affect the availability of P (Marschner, 1995). Organic acids in root exudates can complex Fe and Al, resulting in release of P bound by Fe and Al oxides (Otani and Tanaka 1996). Due to these circumstances differences in soils are related to the efficiency of plants to take up and use soil P. Phosphorus is locked up in acid soils as iron phosphates or aluminium phosphates; Figure 9 demonstrates the dynamics of phosphorus availability in tropical soils influenced by pH and the presence of free iron or aluminium. Abhijit, *et al*., (2010) propose that P analysis of P concentration in third leaf could be used to monitor P status combined with soil tests, the values for relative effectiveness of applied P had been used to estimate fertilizer requirement. Bonheure (1990) found that the normal P concentration of the flush shoot was between 1.8 and 3.9 gkg^{-1} of dry matter, and the critical, P concentration below which responses would be expected was 1.8 gkg^{-1} the results were in contrast to Barooah *et al.* (2005) who found the P concentration in tea leaf ranged from 2.6 to 3.6 gkg^{-1} on dry-weight basis. Furthermore, The results of trials on tea for the plains of India showed that 23.5 kg P ha^{-1}, along with sufficient application of =nitrogen and potassium, was optimum for a yield of 2,300 kg (or higher) made-tea per hectare. Under the treatments increased P concentrations from 3 g kg^{-1} to 4 gkg^{-1} was associated with an increase in yield ranging from 1,200 to 1,800 $kgha^{-1}$ of green leaf tea.

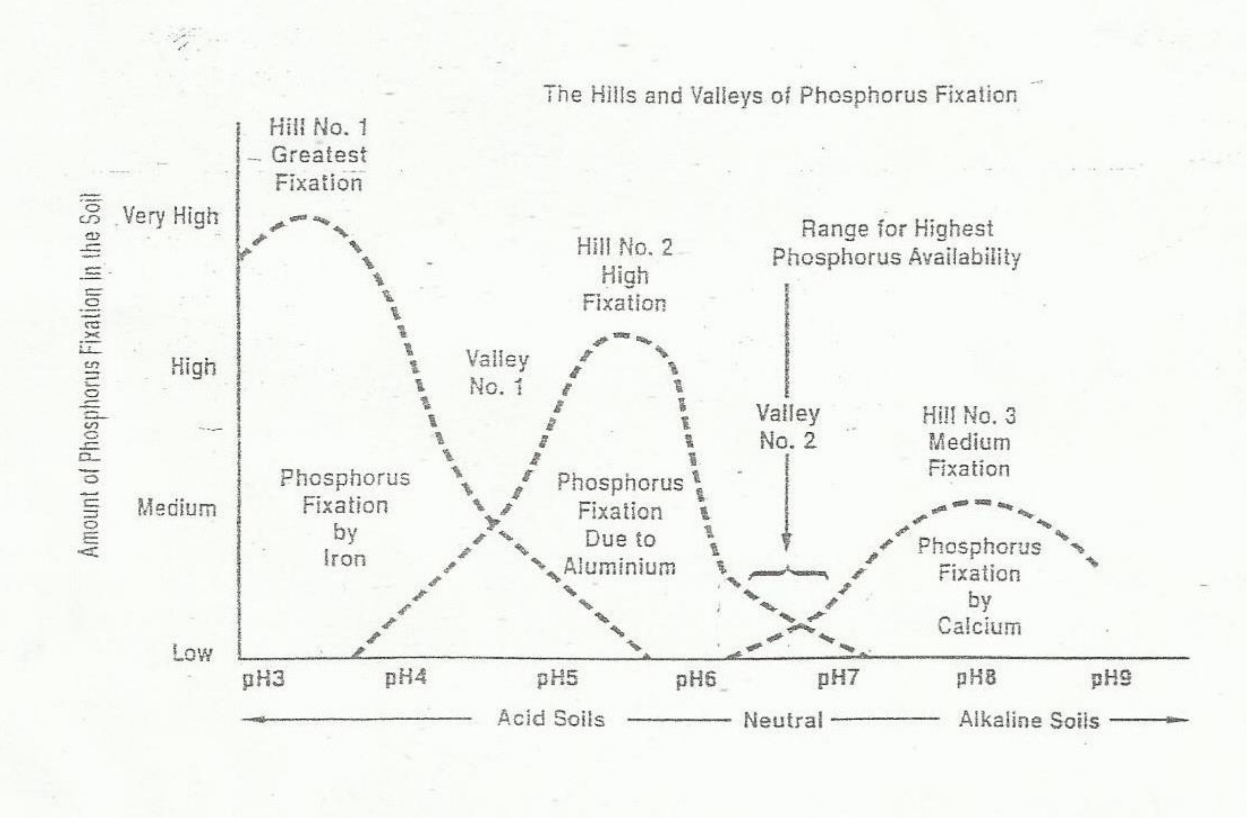

Figure 1 demonstrates the dynamics of phosphorus availability in tropical soils as influenced by pH and the presence of free iron or Aluminium. (Adopted from Cordingley, 2010)

2.6 The concentration of Aluminum in soil and the plants

The concentration of Al in tea products and its release upon infusion has been a topic of numerous studies owing to health concerns on the consumption of Al (Wong *et al.,* 1998). It has been suggested that higher levels of Al in young shoots relate to lower pH and hence higher Al availabilities in the soils (Wong *et al.,* 1998).

Aluminum exists in various forms in the soil: as soluble species in soil solution, adsorbed forms on organic and mineral colloidal surfaces, amorphous and crystalline hydroxy–Al, Al polymerized on clay surfaces and between clay interlaces, and as a structural component of secondary clay minerals (Shuman, 1990; Soon,1993).

This reaction below show that hydrated metal with a charge 3 or more are proton donors and may affect soil acidity. Free Al or hydrated Al ions are usually present in a large amounts in acid soils may cause Al toxicity to plants (Hunt, 1972)

$$Al3^{+} + H_{2}0 \Leftrightarrow Al(0H)2+ + H+$$

$$Al3^{+} + 2H_{2}0 \Leftrightarrow Al(0H)2+ + 2H+$$

$$Al3^{+} + 3 H_{2}0 \Leftrightarrow Al(0H)2 + 3H+$$

$$Al3^{+} + 4H_{2}0 \Leftrightarrow Al(0H)\ 2^{-} + 4H+$$

$$Al3^{+} + 5H_{2}0 \Leftrightarrow Al(0H)2^{-} + 5H+$$

Recent studies have demonstrated that the accumulation of Al in tea plants is significantly affected by the age of organs in tea plants and the specific variety (Wong *et al.,* 1998). The variable Al concentrations in tea plants growing in different types of soils suppose that the absorption of Al is possibly affected by soil conditions and extractable Al levels (Wong *et al.,* 1998). Ruan *et al*, (2000) reported that exchangeable Al in tea field soils and Al in tea leaves, the concentration of exchangeable Al in soil taken from tea fields ranged from 0.03 to 7.32 Cmolc kg^{-1}) and averaged 2.59 Cmolc kg^{-1}) these results shows that the level of Al decreased rapidly with increasing soil pH, reaching a minimum at pH > 5.0. The concentration of Al in mature leaves was (2868–4996 mg kg^{-1}). Furthermore the relationship of Al extracted and Al saturation with soil pH was described well by the semi-empirical equations formerly used by Reuss (Reuss et *al*, 1990)

2.7 Micronutrients in the soils and tea plants

Good soils for tea production should also have adequate supply of both macronutrients and micronutrients for optimum production (Gajbhhiye and Ranganathan, 1998).The elements that are essential but are required in small amounts for the plant growth are known as micronutrients (Marschner, 1995, Tisdale *et al*, 1993). These include Cu, Zn, Mn, Cl and Boron.

2.7.1 Zinc

Usually Zinc occurrence in soils it ranges from 10 - 300 mg Zn/ kg soil (Krauskopf, 1972). Total Zn in soils varies in one soil to another depending on parent materials, soil types, amount of organic matter and clay content. Low portion of it exist in soil solution (Reed and Martens, 1996). Zinc is taken up by plants in the form of Zn^{2+} ions (Marschner, 1995)

Lindsay and Norvel (1978) described the critical level of DTPA extractable Zn to be 0.5 – 1.0 mg Zn kg^{-1} soil and that the amounts of Zn lower than the critical value are considered to be in deficient range. Zinc deficiency is wide spread and its application for tea has become indispensable throughout the world, Usually Zn deficiency in the tea results to the formation of the two or more very small buds from a single axial called a “rosette” one may become dominant and others go banjhi and leaves become yellow (Wilson, 1969).

2.7.2 Copper

Copper in general is very low in many soils; total Cu content in soils varies from one soil to another ranging from 0 to 10 mg/kg (Krauskopf, 1972). It is deficient in ferrallitic and ferruginouscoruse texture soils or calcareous soils derived from chalk and soils of high organic matter where Cu complexes to form co-organic matter complexes (Alloway and Tills, 1984). The complexes Cu became unavailability to plants (Mkangwa, 1992).

Copper deficiencies are common like other micronutrients and should be collected as symptoms /hunger sign appear (Tisdale *et al,* 1993). Cu deficiency in tea causes’ poor fermentation of the tea leaves which reduces quality of the final products (Bonheure and Wilson, 1992). This is because Cu is an essential constituent of the enzyme polyphenol oxidase that is vital for tea fermentation.

2.7.3 Iron

In soils, Fe is abundant element in primary and secondary minerals. In low pH soil sand under reducing conditions, soluble Fe can be present in high concentrations at levels toxic to plants. Iron in soils exists in the form of oxides, hydroxides and organic complexes and as exchangeable Fe^{2+}. In acid soils and reduced soils, Fe^{2+} (which is more soluble) where as in oxidized soils, Fe^{3+} (which is less soluble) is dominant of Iron (Bohn *et al*, 1985). Bonheure and Wilson (1992) establish critical levels for DTPA extractable iron to be 6 mg Fe kg^{-1} soils. In the third leaf of plants, the normal range of Fe is 100 - 500 mg kg^{-1}

In tea, deficiency of Fe is thought to affect growth of the plants and flavor of the made tea (Pethiyagoda and Krishnapillai, 1971), this is due to the fact that the ratio of the Fe/Mn in tea is considered to have large effect on flavor of the made tea.

The main visual symptom of Fe deficiency in tea is the occurrence of the chlorotic mottling of young leaves starting within the interveinal areas of the leaves and growing outwards (Bonheure and Wilson, 1992)

2.7.4 Manganese

The total manganese in soils It occurs as oxides and hydroxide coated on soils particles, in soils Mn exists as Mn^{2+} (Tisdale *et al,* 1993) Deficient of Mn occurs occasionally in soils of very high pH. The deficiency occurs first in the younger leaves in tea (Tandon, 1995). Mn deficient leaves turn pale yellow on the edges and develop a mottling of red brown spots (Bonheure and Wilson, 1992). The interveinal chlorosis of the leaves tend to extend inwardly from inwardly from the margin. In severe cases, apical growth stops, total deformation and defoliation of the leaves occur (Pethiyagoda and Krishnapillai, 1971).

2.8 Rocks and minerals for tea soil in Lushoto

Soils are directly dependent on the properties and features of the parent material, soils are formed by weathering of rocks and rocks are formed by geological processes, thus to understand soils we need to know how the landscapes was formed and which rocks gave rise to soils (Buole *et al*,1980)

In Lushoto district the dominant rocks and minerals are Metamorphic rock (Acid metamorphic). Gneiss, Magmatite rock. Gneiss rock composed minerals such as Feldspars, quartz, micas and pyroxenes. Type of clays: dominant clays are Kaolinite and hydrous oxides. It has a wide variety of soils most distinctive are Acrisols and Luvisols (National soil service 2006).

2.9 Nutrients in soil and plant tissues

Soil fertility is a serious natural resource in any crop production system. Soil fertility it involving to quantify and estimation of nutrients in soil and plant tissues that present in crop and soil systems. Frequency and depth of sampling was critical because tillage and nutrient mobility in the soil can influence nutrient levels in different soil zones. In general sampling depth depends on the crop, cultural practices, tillage depth and the nutrients to be analyzed, plant roots, biological activity and highest nutrient levels occur in the surface layers (0-30cm), hence top soil samples were collected within this layer in this study.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

Lushoto district is located in Tanga region north-east Tanzania. The district lies between latitude 4˚ 46' South of the equator and longitude 38˚ 16' east of Greenwich (Figure 1). Altitude 1675 m. The soil type under tea in Lushoto district is Humic Acrisols with the following properties; deep yellowish or reddish sandy clays moderate to strong structure, with moderate natural fertility; and well drained, (Melliyo and Hiza, 2006) the dominant rocks and minerals are metamorphic rock (acid metamorphic), gneiss, magmatite rock. Gneiss rock composed minerals such as Feldspars, quartz, micas and pyroxenes dominant clays are Kaolinite and hydrous oxides.

First: through a survey conducted in Lushoto district with the aim of evaluates soil macro and micro nutrients status on yields of smallholder tea farms, and to analyze plant tissue nutrients with respect to tea yields. Secondly, an Experiment; TRIT use different types and rates of fertilizers to studying the nitrogen response on four commercial clones yield in the duration of four years which started in 2009/10 to 2012/13, research questions: were there differences in yields of tea when different rates of nitrogen inorganic fertilizer applied during short and long rain season? Are there differences in yields among four tea clones during short and long rain season? in order t**o** gain understanding on those unanswered questions as a result, this experiment was conducted at Marikitanda tea research station.

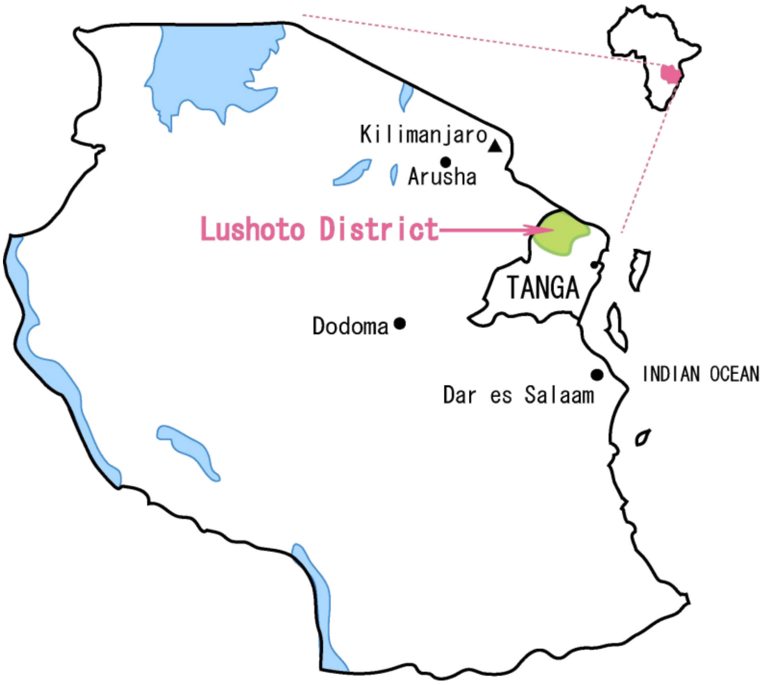

Figure 2. Map of Tanzania the showing study area (Source: Tanga Region profile)

3.2 Climate of the study area

Tea production is mainly depending on number of factors (rainfall, temperature, altitude etc). The mean annual rainfall was in range 1165 - 1960 mm/ year bimodal falling during March – May- long rains and again in October – December- short rains and elevation range from 1000 – 2000 meter above sea level, means temperature was 15 – 25ºC for the period of 2004/10. Data from Mponde Tea Factory Meteorology station, Lushoto, Tanga was given in Appendix VII

3.3 The agro-ecological zones (AEZs) of Tea growing areas

Land Suitability for crop assessment for Tanzania was based on Agro-ecological zones mostly considering several land qualities which mostly influences crop adaptation and sound growth. The land qualities were soil pH, drainage, temperature, rainfall and altitude above sea level and length of dependable growing period (DGP). This report provides detailed instructions on how to utilize the suitability at National and district levels by indicating the agro ecological zone, its characteristics and the crops which are suitable to be grown. (Melliyo and Hiza, 2006).

In Tanzania tea is considered to be divided into three zones: I. Northern zone, Southern zone and Lake zone. II. Northern zone includes Muheza, Korogwe and Lushoto districts. Southern zone includes Dabaga, Mufindi, Njombe, Ludewa, Rungwe and potentially Mbinga districts. III.Lake zone includes Bukoba & Muleba and Tarime districts. (Priest, 2010).

3.4 Nutrients diagnosis for Soil and leaf sampling

Random sampling method was used in each scheme, whereby list of smallholders who grow tea was used to select the list for sampling which divided into two major group of soils and third leaf samples, conducted in four scheme namely Balangai, Mponde, Bumburi and Mazumbai sample size 18, 19, 7 and 8 respectively for Lushoto district, list was given in Appendix V and VIII

3.5 Soil and third leaf sampling procedures

3.5.1 Soil sampling procedure

The soil sampling was carry out within four schemes; Balangai, Mponde, Bumbuli, and Mazumbai in district Samples were collected in zig zag configuration with a soil auger in spots to obtain the sub sample, 10 - 15 auger holes were used, at 0 – 30 cm depth each sub sample was thoroughly mixed in a clean container to form a composite of about 1kg. The schemes name, List of farmer’s name, Village name, elevation and location of the soils samples were shown in Appendix V and VIII.

Samples were put in paper bag, labeled in field packed in boxes then dispatched to Ngwazi Plant and Soil Analysis Laboratory (NTRS) at Mafinga, Iringa for analysis. Laboratory analyses soils were received at the Laboratory. Each sample was logged in with a unique Identity Number. Nutrient analysis in soils: The disturbed soil samples were air dried ground to pass through 2mm sieves to obtain the fine earth fractions for laboratory analyses. The following analyses were carried out; Soil pH (H_2O and KCl), Electrical conductivity, Organic carbon, Cation exchange capacity (CEC), Total nitrogen, Available phosphorus, Exchangeable acidity, Exchangeable cations of K, Ca, Mg, Na, S. Micro nutrients Zn, Cu, Fe, Mn, and Particle size determination, following methods described by Okalebo *et al.*, 2002 .

3.5.2 Leaf sampling procedure

The sampling was conducted within four schemes; Balangai, Mponde, Bumbuli, and Mazumbai in Lushoto district. The third leaf was selected from mature tea plant leaves surrounding the auger holes (10 - 15) area where the soil sample taken, a total of 100 leaves made a one sample from a shoots supporting an actively growing shoot of two leaves and a bud, were collected as a leaf sample, placed in well labeled paper bag in a field and store in ice cool box. The schemes name, List of farmer's name, Village name, elevation and locations of the leaf samples as illustrate in Appendix V and VIII.

Leaf samples were dispatched and stored to Ngwazi Plant and Soil Analysis Laboratory (NTRS) at Mafinga, Iringa. Nutrient analysis in plants third leaf: The plant materials were put in oven for 4 hours to dry, the moisture of the plant sample must be kept very low by drying at 70ºC oven dry before weighing, the moisture content should be 1 - 2%, third leaf analysis for macronutrients N, P, K, Ca, Mg, S and micronutrients Cu, Zn, Fe, and Mn**.** following methods described by Okalebo *et al.,* 2002.

3.6 Experiment on Nitrogen Fertilizer use (on-going experiment)

Field Experiment: TRIT's experiment established in 2009/10 was used for this study. The experiment uses different types and rates of fertilizers to investigate the response of four commercial clones to nitrogen application. Research questions**:** are there differences in yields of tea when different rates of mineral nitrogen fertilizer are applied during short and long rain season? Are there differences in yields among four tea clones during short and long rain season? in order to answer those test established experiment of N were at Marikitanda tea research station where soils are highly depleted

3.6.1 Initial soil test for fertility status of fertilizer use ongoing experiment

Soil composite samples were taken from each plot prior to start experiment in 2009/10 and at the end of experiment in 2012/13 for the purpose of monitoring the change in soil fertility plots planted with different tea clones and receiving different rates of N fertilizer condition Appendix IV

3.6. 2 Treatments

The experiment consisted of two factors, clone and nitrogen the factor clones had 4 levels clone; K 7, K 35, 282 and 207. The factor nitrogen fertilizer had 8 levels levels; 0, N_0; 40, N_1; 80, N_2; 120, N_3; 160, N_4; 200, N_5; 240, N_6; 280, N_7 Source of N fertilizer was Urea 46% N. These applied as basal to all plots except control plots Triple super phosphate 40 kg P /ha and Muriate of potash, 187 kg k / ha were applied two equal splits in all plot in short and long rain seasons.

3.6.3 Experiment description and specification.

Design: 4 x 8 factorial experiment in a randomized complete block design, replicated three times

Plot specification: Spacing of 0.9 x 1.2 m, net plot size 3 x 4.8 m ($14.4m^2$) each net plot occupied by bushes 20 bushes and surrounded by three rows of guard plants. Plant population was 9,259 plants /ha. Experimental field layout given in Appendix II.

Plucking duration Plucking interval 12 − 14 days depend on weather conditions per season.

3.6.4 Statistical analysis

- Data analysed using GENSTAT statistical package version 12^{th}
- Treatment effect assessed by ANOVA.
- Mean separationby Tukeys HSD.

3.7 Two factors experiment Model

- $\gamma = \mu + \alpha_i + \beta j + \beta ij + \Sigma_{ijk}$

  - γ = Dependent variables in that case green leaf tea as a Yield.
  - μ = Treatments mean.
  - α_i = treatment cropping system refer to clones.
  - β_j = rate of N application.
  - βij = interaction between clones and Nitrogen fertilizer level.
  - Σ_{ij} = the error term.

CHAPTER FOUR

RESULTS

4.1 Chemical and physical characteristics of the soil in studied schemes

The Chemical and physical characteristics of the soils in four schemes given in Table 1 and Table 2. The analysis results are interpreted using the TRIT soil test data guidelines by Kimambo and Lupembe, (2010) in Appendix IIIA and IIIB.

Table 1: Soil chemical and physical characteristics of study tea schemes in Lushoto district.

Schemes name / Soil parameter	Balangai	Mponde	Bumbuli	Mazumbai	Mean	
-pH(H_2O)	5.07	4.73	5.04	5.09	4.98	
-pH(KCl)	4.72	4.35	4.73	4.63	4.61	-
TN(%)	0.20	0.14	0.21	0.20	0.19	
OC(%)	2.77	2.74	2.79	2.75	2.76	-
OM	4.77	4.71	4.80	4.74	4.76	
Available P (Cmole/kg)	2.12	3.29	2.49	3.11	2.75	
Extract S (Cmole/kg)	3.04	3.03	3.11	3.03	3.05	
CEC (Cmole/kg)	9.03	7. 29	9.16	9.80	8.82	
Bases (Cmole/kg)						
Ca^{2+}	9.20	5.41	15.7	12.01	10.58	
Mg^{2+}	2.79	2.17	3.91	3.20	3.02	
K^{+}	0.21	0.15	0.27	0.24	0.22	
Na^{+}	0.13	5. 41	0.12	0.14	1.45	-
Cu (ppm)	1.85	0.43	1.36	1.24	1.22	
Mn (ppm)	12.3	12.52	12.49	12.9	12.55	
Fe (ppm)	13.20	14.91	16.98	16.1	15.29	
Zn (ppm)	0.72	0.01	0.77	0.85	0.59	
Al^{3+}	4.68	3.26	1.20	1.68	2.4	
Exchangeable acidity	3.07	6.55	2.86	3.79	4.07	-
Particle size						
% Sand	51	53	56	58	55	-
% Silt	34	33	34	32	33	-
% Clay	15	14	10	10	12	-

Table 2: The range for soil chemical and physical characteristics of study tea

Schemes name / Soil parameters	BALANGAI	MPONDE	BUMBULI	MAZUMBAI
	Min - Max	**Min - Max**	**Min - Max**	**Min - Max**
.pH(H_2O)	4.18- 5.97	4.14 – 5.43	4.49 – 5.44	4.39 – 5.97
.pH(KCl)	4.17- 5.27	4.11 – 4.99	4.38 – 5.11	4.17 – 4.98
TN(%)	0.07 – 0.3	0.07 – 0.26	0.09 – 0.3	0.08 – 0.29
OC(%)	2.00 – 2.85	2.21 - 2.85	2.67 – 2.92	2.45 – 2.84
OM	4.47 – 4.91	3.81 – 4.91	4.60 – 5.02	4.22 – 4.90
P Bray-1(Cmole/kg)	0.61 – 4.57	0.78 – 8.90	1.30 – 6.28	0.96 – 11.79
Extract(Cmole/kg)	1.60 – 4.63	1.55 – 4.57	1.5 – 4.95	1.75 – 4.34
CEC (Cmole/kg)	5.12 – 12.00	2.94 –10.65	5.95 – 11. 72	6.84 – 12.19
Bases (Cmole/kg)				
Ca^{2+}	0.99 – 37.44	0.02 – 21.71	0.75 – 33.54	0.64 – 32.26
Mg^{2+}	0.38 – 4.73	0.01 – 4.95	2.58 – 4.82	0.65 – 4.84
K^+	0.10 – 0.35	0.10 – 0.26	0.16 – 0.42	0.10 – 0. 43
Na^+	0.10 – 0.17	0.02 – 21.71	0.08 – 0.14	0.11 – 0.17
Cu (ppm)	0.12 – 4.92	0.03 – 1.22	0.33 – 2.71	0.48 – 2.13
Mn (ppm)	1.94 – 21.31	3.6 – 20.8	4.94 – 20.65	3.99 – 20.94
Fe (ppm)	1.85 – 19.18	2.0 – 21.18	10.05 –21.39	11.68 – 20.63
Zn (ppm)	0.10 – 2.04	0.01 – 6.65	0.09 – 2.24	0.15 – 3.25
Al^{3+}	0 – 4.68	0.37 – 5.16	0 – 3.93	0 – 4.46
Exchangeable acidity	0.02 - 7.51	0.9 – 10.68	0.47 – 8.27	0.59 – 9.33
Particle size analysis				
% Sand	39.20 – 59.20	29.7 –69.20	49.20 –69.20	39.2 0– 69.20
% Silt	25.4 – 42.4	23.4 –45.40	25.4 – 40.4	25.4 – 40.4
% Clay	7.4 – 20.4	5.4 – 25.4	5.4 – 15.40	5.40 – 20.40

4.2 Soil reactions

The pH of the soils determined in 1: 2.5 soils: water ratio in are summarized in Table 1 and Table 2. In Balangai scheme with a mean value of 5.07 with a range of 4.18 – 5.97. In Bumbuli a mean value was 5.04 with a range of 4.14 – 5.43. In Mazumbai a mean pH was 5.09 range of 4.49 – 5.44. In Mponde a mean pH was 4.73 with range of 4.39 – 5.97. The optimum range of soil pH for the tea plant is 5.0 to 5.6. The soils in four schemes were therefore suitable for growing tea.

4.3 Aluminium and Exchangeable acidity

The results of Aluminium and Exchangeable acidity from study area are summarized in Table 1 and Table 2. In Balangai scheme the results exposed that the mean of Aluminium and Exchangeable acidity was 3.07 and 4.68 with ranges from 0 - 4.68.and 0.02 - 7.51 In Mponde scheme the results had shown the mean of 3.26 and 6.55 with range from 0.37 - 5.16. In Bumbuli scheme the results suggest that, the mean 1.20 and 2.86 with range 0 - 3.93 and 0.47 - 8.27. In Mazumbai scheme the results revealed mean of 1.68 and 3.79 the range was from 0 - 4.46 and 0.59 - 9.33 The mean value in four schemes in Lushoto district was 2.3 and 4.47 Aluminium and Exchangeable acidity respectively. The results implies that all farms were not in toxic level in view of the fact that Aluminum in soils; > 30 ppm is considered toxic for tea production.

4.4 Soil macro nutrient elements

4.4.1 Total Nitrogen

The totals N for the soils under study are summarized in Table 1 and Table 2. In Balangai scheme the mean value was 0.2 with range from 0.07 - 0.3. In Bumbuli scheme the mean value was 0.21 with range from 0.09 - 0.3. In Mazumbai scheme the mean was 0.20 with the range from 0.08 - 0.29. Mponde scheme had the lowest value of the mean of 0.14 with range of 0.07 - 0.26.The mean value of Total nitrogen in four schemes in Lushoto district was 0.19. According to Kimambo and Lupembe, (2010) soils are categorized as deficiency < 0.25%N.

4.4.2 Available phosphorus

The Bray-1 extractable P for the soils are shown in Table 1 and Table 2. In Mponde scheme had the mean of 3.29 with range of 0.78 - 8.90. In Bumbuli scheme had the mean 2.49 with range 1.30 - 6.28. In Mazumbai scheme the results showed mean was 3.11 and the range was 0.96 - 11.79. Balangai scheme had the lowest value of the mean of 2.12 with range from 0.16 - 4.57. The mean value of Available phosphorus in four schemes in Lushoto district was 2.75 Based on kimambo and Lupembe, (2010) available P was in deficiency (< 10 Cmole/kg).

4.4.3 Potassium

The exchangeable K in the soils are presented in Table 1 and Table 2. In Balangai scheme the results show the mean of 0.21 with range from 0.1 - 0.35. In Mponde scheme the results have shown the mean of 0.15 with range from 0.1 - 0.26. In Bumbuli scheme the results show the mean of 0.27 with range from 0.16 - 0.42. In Mazumbai scheme the results revealed mean of 0.24 and the range was 0.10 - 0.43. The mean value of Potassium in four schemes in Lushoto district was 0.22 Cmole/kg According to the guide by kimambo and Lupembe, (2010) all farms had low K level.

4.4.4 Available sulphur

The exchangeable sulphur (S) in levels in study area are summarized in Table 1 and Table 2. In Balangai scheme the results show the mean of 3.04 with range from 1.60 - 4.63. In Mponde scheme the results had shown the mean of 3.03 with range from 1.55 - 4.57. In Bumbuli scheme the results show the mean of 3.11 with range from 1.5 - 4.95. In Mazumbai scheme the results show mean of 3.05 and the range of 1.75 - 4.34. The mean value of Available sulphur in four schemes in Lushoto district was 3.05. According to Kimambo and Lupembe, (2010), farms in study area had optimal level of soil S (3.0- 4.0).

4.4.5 Magnesium

The exchangeable Mg levels in the study area shown in Table 1 and Table 2. In Balangai scheme the results show the mean of 2.79 with range from 0.38 - 4.73. In Mponde scheme the results shown the mean of 2.17 with range from 0.01 - 4.95 In Bumbuli scheme the results suggest that, the mean of 3.91 with range of 2.58 - 4.82. In Mazumbai scheme the result revealed mean of 3.20 and the range from 0.65 - 4.84. The mean value of Magnesium in four schemes in Lushoto district was 3.02 Cmole/kg. According to kimambo and Lupembe, (2010) Mg in soils was within the optimal level of (3.0 - 4.0).

4.4.6 Calcium

The results on Ca levels are shown in Table 1 and Table 2. In Balangai scheme the results show mean of 9.20 with range from 1.00 - 37.44. In Mponde scheme the results show the mean of 5.41 with range from 0.02 - 21.71. In Bumbuli scheme the result show the mean of, the mean 15.7 with range of 0.75 - 33.54. In Mazumbai scheme the results show the mean of 12.01 and the range of 0.64 - 32.26. The mean value of calcium in four schemes in Lushoto district was 10.58. According to Kimambo and Lupembe, (2010) most farms were rich with Ca (optimal level; 1.0 - 2.0 Cmole/kg).

4.5 Organic carbon and Cation exchange capacity

4.5.1 Organic Carbon

The organic Carbon multiplied (by factor 1.72) gives the organic matters in the soil content are presented in Table 1 and Table 2. In Balangai scheme the results show that the mean value was 4.77 with range from 4.47 - 4.91. In Mponde scheme the results indicate the mean of 4.71 with the range value from 3.81 - 4.91. In Bumbuli scheme the result show, the mean of 4.80 are range of 4.60 - 5.02. In Mazumbai scheme the result show that mean of 4.74 and the range of 4.22 - 4.90. The mean value of Organic matter in four schemes in Lushoto district was 4.76. According to Kimambo and Lupembe (2010). There were optimal amount of organic matter (3.0-5.00%) in almost all tea field in study area.

4.5.2 Cation exchange capacity (CEC)

The CEC results of the study sites are summarized in Table 1 and Table 2. In Balangai scheme the results show the mean of 9.03 with range from 5.12 - 12.00. In Mponde scheme the results show the mean of 7.29 with range of 2.94 - 10.65. In Bumbuli scheme the result show, the mean of 9.16, with range of 5.95 - 11.72. In Mazumbai scheme the results show the mean of 9.80 and the range from 6.84 - 12.19. The mean value of CEC in four schemes in Lushoto district was 8.82). According to Kimambo and Lupembe, (2010), all farms fell below the optimum level of 15-25 Cmole/kg.

4.6 Some micro nutrient elements in soils

4.6.1 Zinc

The amount of extractable Zn is presented Table 1 and Table 2. In Balangai scheme the results show the mean of 0.72 and range from 0.10 - 2.04. In Mponde scheme the results show the mean of 0.01 with range from 0.01 - 6.65. In Bumbuli scheme the results show the mean of 0.77 with range from 0.09 - 2.24. In Mazumbai scheme the results indicate the mean of 0.85 and range 0.18 - 3.25. The mean value of Zinc in four schemes in Lushoto district was 0.59. According to Kimambo and Lupembe, (2010) categories in levels of Zn, all soils in tea farms were below optimal level (15.0-20.0 ppm).

4.6.2 Copper

The amounts of extractable Cu are presented in Table 1 and Table 2. In Balangai scheme the results indicate that the mean 1.85 with range from 0.12 - 4.92. In Mponde scheme the results show the mean of 0.43 with range from 0.03 - 1.22. In Bumbuli scheme the results indicate the mean of 1.36 with range from 0.33 - 2.71. In Mazumbai scheme the result show that mean of 1.24 and the range was 0.48 - 2.13. The mean value of Copper in four schemes in Lushoto district was 1.22. Kimambo and Lupembe, (2010), categories in levels of Cu, all soils in tea farms were below optimal level (15.0-20.0 ppm).

4.6.3 Iron

The available Fe contents of soils are presented in Table 1 and Table 2. In Balangai scheme the results show the mean 13.2 with range 1.85 - 19.18. In Mponde scheme the results have shown mean of 14.91 with range from 2.0 - 21.18. In Bumbuli scheme the results indicate the mean 16.98 with range 10.05 - 21.39. In Mazumbai scheme the results indicate that mean of 16.1 and the range 11.68 - 20.63, The mean value of Iron in four schemes in Lushoto district was 15.29. According to Kimambo and Lupembe, (2010) all soils in tea farms, were almost in optimal levels (above 10 ppm).

4.6.4 Manganese

The amount of extractable Mn is presented in Table 1 and Table 2. In Balangai scheme the results show the mean 12.3 with range 1.94 - 21.31. In Mponde scheme the results shown the mean of 12.52 with range from 3.4 - 20.8   In Bumbuli scheme the result indicate the mean of 12.49 with range from 4.94 - 20.65. In Mazumbai scheme the result show that mean of 12.9 and the range was 3.99 - 20.94. The overall mean value of Manganese in four schemes in Lushoto district was 12.55. Kimambo and Lupembe, (2010) suggested the critical limit of Mn as 10 ppm, almost the farms had adequate amount of Mn,

4.7 Soil physical analysis results

Soil texture analyses results are tabulated according to the schemes followed by mean values for the schemes in Lushoto district Table 1 and Table 2. The mean; %Sand was 52 had a range from 39 - 59, %Silt mean was 35 had a range from 25 - 42, %Clay mean was 13 range of 7 -

20. Mponde scheme %Sand mean was 53 had a range from 29.7 - 69, %Silt mean was 35 and range from 23 - 45, %Clay mean was 12 had a range from 5 - 25. Bumbuli scheme %Sand mean was 56 had a range from 49 - 69. %Silt mean was 34 had a range from 25 - 40, %Clay mean was 10 it range from 5 - 15. Mazumbai scheme %Sand mean was 58 had a range from 39 - 69, %Silt men was 32 had a range from 25 - 40, and % Clay mean was 9 had a range from 5 - 20.

4.8 Chemical analysis results of third leaf

Table 3 and Table 4 shows the mean and range respectively, chemical contents of third leaf from the four schemes in Lushoto district. The results are interpreted using the TRIT plant tissue analysis guidelines developed by Kimambo and Lupembe, (2010) Appendix IIIA and IIIB

Table 3: The mean third leaf nutrient contents are recorded in different Smallholder tea schemes in Lushoto district in Tanga region

Schemes name / Leaf parameter s	Balangai	Mponde	Bumbuli	Mazumbai	Optimal Levels (mean)	
N %	0.14	0.19	0.18	0.15	0.17	2.00-5.00
P (%)	0.31	0.32	0.35	0.33	0.32	0.3 -0.5
K %	3,05	3.35	2.89	3.32	3.15	2.0- 5.00
Ca %	5.78	5.0	5.9	5.14	5.45	0.2-5.00
Na %	0.05	0.05	0.05	0.05	0.05	0.04-0.06
Mg %	0.88	0.92	0.93	0.90	0.90	0.2 -0.4
Cu (ppm)	19.29	18.45	13.88	15.56	16.79	20.0-25.0
Mn (ppm)	725.00	755.0	747.3	632.10	714.85	15.0-20.0
Zn (ppm)	32.29	29.64	23.31	24.21	27.36	15.0 -20.0
Fe (ppm)	54,33	68.44	81.22	48.89	63.22	5.0-10.0
S (ppm)	1.32	1.31	1.31	1.22	1.29	0.3- 0.5

Table 4: The range for third leaf nutrients contents are recorded in different Smallholder tea schemes in Lushoto district in Tanga region

Schemes name / Plant parameter	BALANGAI Min - Max	MPONDE Min - Max	BUMBULI Min - Max	MAZUMBAI Min - Max
N(%)	0.02 – 0.25	0.07 – 0.3	0.09 – 0.26	0.07 – 0.21
P (%)	0.26 – 0.42	0.13 – 0.70	0.31 – 0.36	0.25 – 0.59
K %	1.74 – 4.67	2.06 – 5.54	2.28 – 4.78	1.74 – 4.89
Ca %	4.15 – 6.92	0.05 - 0.06	3.8 – 6.78	4.48 – 7.45
Na %	0.05 – 0.06	0.05 – 0.06	0.05 – 0.06	0.05 – 0.06
Mg %	0.8 – 0.97	0.87 – 0.89	0.84 – 0.97	0.91 – 0.95
Cu(ppm)	11.25 – 32.75	9.0 – 42.04	12.0 – 19.25	11.0–16.75
Mn(ppm)	218.8 – 1418.0	113 – 1546	88.25 – 950.8	204. –1346
Zn(ppm)	10.75 – 79.75	12.75 – 50	10.25 – 35.5	10.25–42.75
Fe(ppm)	14.25 – 12.0	5.5 136.5	19.5 – 80.25	13.5 –129.5
S(ppm)	0.08 -1.9	0.4 – 75	0.04 – 1.85	0.35 – 1.76

4.8.1 Nitrogen

The contents of N in the third leaves of tea plants are shown in Table 3 and Table 4. In Balangai scheme the results show that the mean N value was 0.14 with range of 0.02 - 0.25. In Bumbuli scheme the results show, the mean of 0.18 with range from 0.09 - 0.26. In Mazumbai scheme the results indicate that mean of 0.15 and the range from 0.07 - 0.21. Mponde scheme had the lowest N value mean of 0.19 with range of 0.07 - 0.3.The mean value of Total nitrogen in four schemes in Lushoto district was 0.17. According to kimambo and Lupembe, (2010) nitrogen level is categorized as deficient (if N <2.5%).

4.8.2 Phosphorus

The content of P in third leaves of tea plants are shown in Table 3 and Table 4. In Balangai scheme the results show that the mean was 0.36 with range from 0.26 - 0.42. In Mponde scheme the results show the mean of 0.32 with range from 0.13 - 0.70. In Bumbuli scheme the results indicate that, the mean 0.33 with range from 0.25 - 0.59. in Mazumbai scheme the results show the mean of 0.35 with a range from 0.25 - 0.59. The mean value of Phosphorus in four schemes in Lushoto district was 0.32. Kimambo and Lupembe, (2010) Categorize P for the third leaf of tea plant (0.3 - 0.5% as optimal level). Most farms were above optimal level.

4.8.3 Potassium

The content of K in the third leaves tea plant is shown in Table 3 and Table 4. In Balangai scheme the results indicate that the mean was 3.05 with range 1.74 - 4.67. In Mponde scheme the results show the mean of 3.35 with range from 2.05 - 5.54.In Bumbuli scheme the results show that, the mean 3.32 with range 2.28 - 4.74 In Mazumbai scheme the results indicate mean of 2.89 with a range of 1.74 and 4.89. The mean value of Potassium in four schemes in Lushoto district was 3.15. According to Kimambo and Lupembe (2010) these results show that tea plants in study area were in optimal level (2.00 - 5.00%).

4.8.4 Sulphur

The S content of the third leaves of tea shoots are summarized Table 3 and Table 4. In Balangai scheme the results show that the mean was 1.32 with range 0.08 - 1.9. In Mponde scheme the result show the mean of 1.31 with range from 0.4 - 7.5 .In Bumbuli scheme the result indicate that, the mean 1.22 with range 0.04 - 1.85. In Mazumbai scheme the result show mean of 1.31 with a range from 0.35 - 1.76. The mean value of Total Sulphur in four schemes in Lushoto district was 1.28. According to Tandon (1995), Kimambo and Lupembe, (2010) the critical limit of S in the third leaf of tea plants is 0.1% the results imply that almost tea farms were in optimum to excess S.

4.8.5 Calcium

The contents of Ca in the third leaves tea plants are show Table 3 and Table 4. In Balangai scheme the results indicate that the mean was 5.78 with range 4.15 - 6.92. In Mponde scheme the result had show the mean of 5.0 with range from 4.00 - 6.00. In Bumbuli scheme the result indicates that, the mean 5.14 with range 3.8 - 6.78. In Mazumbai scheme the result show mean of 5.9 with a range from 4.48 - 7.45. The mean value of Total Calcium in four schemes in four schemes in Lushoto district was 5.45 According to Kimambo and Lupembe (2010) almost tea plants in study area had excess Ca concentration in their third leaf.

4.8.6 Magnesium

The contents of Mg third leaves tea plants are show in Table 3 and Table 4. In Balangai scheme the results indicate that the mean was 0.88 with range 0.8 - 0.97. In Mponde scheme the result show the mean of 0.92 with range from 0.87 - 0.89.In Bumbuli scheme the result indicate that, the mean 0.90 with range 0.84 - 0.97. In Mazumbai scheme the result show mean of 0.93 with a range of 0.91 - 0.95). The mean value of Total Magnesium in four schemes in Lushoto district was 0.90. Based to Kimambo and Lupembe, (2010) these results put forward that most tea farms were in (optimal level 0.2 - 0.4%)

4.9 Micronutrients in third leaf of tea plants

4.9.1 Copper

The Cu in ppm in concentration in tea third leaf of tea plants is presented in Table 3 and Table 4. In Balangai scheme the results indicate that the mean was 19.29 with range from 11.25 - 32.75. In Mponde scheme the results show the mean of 18.45 with range from 9.0 - 42.04 .In Bumbuli scheme the results show that, the mean 15.56 with range 12.0 - 19.25. In Mazumbai scheme the result show mean of 13.88 with a range of 11.0 - 16.75. The mean value of Copper in four schemes in Lushoto district was 16.79. Kimambo and Lupembe, (2010) reported the critical level of Cu in the tea third leaf to be (20ppm). In view of this critical limit all schemes mean values were below the optimal level

4.9.2 Manganese

The concentrations of Mn in ppm in the third leaf are presented in Table 3 and Table 4. In Balangai scheme the results indicate that the mean was 768.00 with range 188.8 - 1418.6 In Mponde scheme the result show the mean of 755.0 with range from 133.00 - 1546.In Bumbuli scheme the result show that, the mean 632.10 with range 88.35 - 950.8. In Mazumbai scheme the result indicate mean of 747.3 with a range of 204.5 - 1346.00. The mean value of Manganese in four schemes in Lushoto district was 725.5. Bonheure and Wilson (1992), categorized the Mn contents in the third leaf of tea shoots as follows <50ppm deficient, 50-100ppm Subnormal, 100 - 500 ppm normal and >5000 ppm in excess. Kimambo and Lupembe, (2010) categorized the Mn contents in the third leaf of tea shoots (in optimal levels 100 - 400 ppm) in view of these categorization of farms in the study area falling under the excess.

4.9.3 Zinc

The concentration of Zn in ppm in third leaf tea plants are show in Table 3 and Table 4. In Balangai scheme the results that the mean 32.29 range from 10.75 to 79.75 In Mponde scheme the results show the mean of 29.64 with range from 12.73 to 50.0. In Bumbuli scheme the results show that, the mean 24.21 with range 10.25 - 35.5. In Mazumbai scheme the results indicate mean of 23.31 with a range from 10.25 - 42.75. The mean value of Copper in Lushoto district was 27.36. According to Kimambo and Lupembe, (2010) most tea plants had the optimal level (15.0 - 20.0).

4.9.4 Iron

The concentration of Fe in ppm in the third leaf tea plants was show in Table 3 and Table 4. In Balangai scheme the results show that the mean was 13.03 with range 12.25 - 14.0. In Mponde scheme the results had show the mean of 36.51 with range from 5.51 - 68.44. In Bumbuli scheme the results indicate that, the mean 48.89 with range 19.5 - 80.25. In Mazumbai scheme the result show mean of 81.22 with a range of 13.5 - 129.5. The mean value of Iron in four schemes in Lushoto district was 63.22. According to Kimambo and Lupembe (2010) Reported as an (optimal level of iron 5.0 - 10.0 ppm) most farms were above optimal level.

4.10 Yield results; on station experiment

The dried tea yields mean results during the short rain season are summarized in Table 5. The treatments of N fertilizer and four clones, there was significant differences ($p < 0.001$) in yields between clones and N fertilizer levels. No significant interactions between the clones and nitrogen fertilizer were statistically found.

Nitrogen fertilizer responses, results show treatment 280 kg N/ha had highest yield (1502 kg/ha). The lowest yields were obtained from the control 0 kg N/ha with yield of 796 kg/ha. The mean yield obtained across the treatments 160, 200, 240, 280 kg (N_4, N_5, N_6, N_7)N/ha (1351bd, 1388cd, 1466cd and 1502d), were no significant different, these results implies that yield increases with increasing in applied N fertilizer to attain reasonable yield in short rain seasons, therefore it need to apply 160 kg N/ha statistically found. The results for clones indicate that clone 207 had the lowest yield (803 kg/ha). Clones K 35, K 7 and 282 were no significant different in mean yield 1381b, 1323b and 1491b kg/ha respectively

Table 5: The dried tea yields mean results on rates of nitrogen fertilizer and four tea clones during short rain season (2010, Marikitanda Tanga)

	Nitrogen rates (kg ha^{-1} yr^{-1})								
	N_0	N_1	N_2	N_3	N_4	N_5	N_6	N_7	
Treatment	**0**	**40**	**80**	**120**	**160**	**200**	**240**	**280**	
Clone									**Mean**
K35	739ae	1096ag	1382bg	1492eg	1510fg	1523fg	1635fg	1671fg	**1381b**
K7	965af	1253ag	1326bg	1373bg	1377bg	1396cg	1427dg	1467eg	**1323b**
282	983af	1303bg	1324bg	1465eg	1600fg	1650fg	1799g	1807g	**1491b**
207	496a	632ab	654ac	679ad	917af	983af	1002af	1062ag	**803a**
Mean	**796a**	**1071ab**	**1171bc**	**1252bc**	**1351bd**	**1388cd**	**1466cd**	**1502d**	**1250**

Cv(%) 18

The dried tea yields results for the long rain season are reported in table 6, the treatments of N fertilizer and four clones. The mean yields (Grand mean) was 2512 kg/ha. There were significant differences ($p < 0.01$) in mean yield among fertilizer treatments. In clones treatments there were significant differences ($p < 0.001$) among clones. No significant interactions between the clones and nitrogen fertilizer were statistically found.

Nitrogen fertilizer responses, the trends show that treatment 280 kg N/ha had highest yield (2996 kg/ha) significant different with control (0 kg N/ha), also from treatment 120 to 280 kg N/ha (N_3 N_4 N_5 N_6 N_7) was insignificant (2694cd, 2761cd, 2871cd, 2937 and 2996d). These results implies that yield increases with increasing in applied N fertilizer to attain reasonable yield in long rain seasons, therefore it need to apply 120 kg N/ha statistically found. The results indicate that clone 207 had highest yield (2964 kg/ha) was significant different with K 7, K 35 and 282. Clone K7 had the lowest yield (2079 kg/ha).

Table 6. Dried tea yields by rates of nitrogen and four tea clones during long rain season (2010 Marikitanda, Tanga)

	Nitrogen rates (kg ha^{-1} yr^{-1})								
Treatment	**N_0**	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**	**N_6**	**N_7**	
	0	**40**	**80**	**120**	**160**	**200**	**240**	**280**	
Clone									**Mean**
K35	1135a	1976ae	2703be	2789ce	2955de	3021de	3114de	3217de	**2614b**
K7	1202a	1887ad	1950ad	2152ae	2206ae	2361ae	2361ae	2481ae	**22079a**
282	1315ab	1993ae	2201ae	2572ae	2593ae	2790ce	2822ce	2851ce	**2392ab**
207	1400ac	2790ce	2805ce	3263de	3289de	3310de	3421e	3435e	**2964c**
Mean	**1263a**	**2162b**	**2415b**	**2694cd**	**2761cd**	**2871cd**	**2937cd**	**2996d**	**2512**

Cv (%) 20

The Annual mean yield results of dried tea for rates of nitrogen fertilizer and four clones are presented in Table 7. On nitrogen rate responses, the results indicate that treatment 280 kg N/ha had overall highest yield 4539 kg/ha and significant differences to control (0 kg N/ha) 1984 kg/ha. Treatments 120, 160, 200, 240 and 280 kg N/ha were no significant differences, generally the results show that 120 kg N/ha this rate is advisable to use.

Responses of clones to nitrogen fertilizer, the yield trend revealed that clones 282 had highest yield of 4288 kg/ha, followed by clone K 35, no significant differences between the two. Also clone K 7 had lowest yield of 3299 kg/ha significant differences with clone 207, the results imply that clone 282 and K 35 were high yield.

Table 7: Annual mean yield of dried tea for rates of nitrogen and four tea clones

(2010 Marikitanda, Tanga)

	Nitrogen rates (kg ha^{-1} yr^{-1})								
Treatment	**N_0**	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**	**N_6**	**N_7**	
	0	**40**	**80**	**120**	**160**	**200**	**240**	**280**	
Clone									**Mean**
K35	1773a	3072ad	4084df	4281df	4465df	4545df	4748ef	4888f	**3982b**
K7	2067ac	3140ae	3276af	3525bf	3673cf	3857df	3908df	4012df	**3432a**
282	2198ac	3297af	3525bf	4037df	4193df	4441df	4621df	4658df	**3871b**
207	1896ab	3423af	3459bf	3942df	4306df	4393df	4490df	4597df	**3813ab**
Mean	**1984a**	**3233b**	**3586bc**	**3946cd**	**4159cd**	**4309d**	**4442d**	**4539d**	**3775**

Cv (%) 13

CHAPTER FIVE

DISCUSSIONS

5.1 Chemical and physical characteristics in the studied Schemes

5.2.1 Soil reaction

The pH of the soils determined in 1: 2.5 soil: water ratio in are summarized in Table 1 and Table 2. Othieno (1992) explained that the optimum range of soil pH for the tea plant is 5.0 to 5.6. However, soils with a pH between 4.5 and 5.5 are acidic but still suitable for tea growing, similar pH values were obtained by other workers in tea growing soils in Mbeya, Njombe, Rungwe and Mufindi (Tanzania),Kamasho, 1980; Mhosole, 1995; Kitundu, 2001; Ndunguru, 2003)

5.2.2 Aluminum and Exchangeable acidity

The results of Aluminum and Exchangeable acidity from study area are presented in Table 1 and Table 2 from the schemes. The results implies that all farms were not in toxic level in view of the fact that Aluminum in soils > 30 ppm is considered toxic for tea production. However, those farms with pH less than 5 were at risk for Aluminum toxicity. The relationship between pH and aluminum it is critical to understand the influence of pH on aluminum toxicity in the soils of tea farms, the mean values for soil pH was 4.98 (strong and very strong) Aluminum decreased rapidly with increasing soil pH. Cordingley, (2010) point out that Aluminum toxicity is common in tropical soils, which reduces root development and therefore limits yield through reduced nutrient and water uptake indicating crop yield decline at higher aluminum saturations.

5.2.3 Organic carbon

The Organic Carbon multiplied by factor 1.72 gives the organic matter in the soil content are presented in Table 1 and Table 2, from the schemes. According to Kimambo and Lupembe (2010) there were optimal amount of organic matter (3.0-5.00%) in almost all tea field in study area. the same findings were reported by Uexkull, (1984); Pennock *et aI.*, (1994); Acton and Gregorich, (1995). As the age of the tea plants in the field increased (30 years old), the rates of OM decomposition and organic matter restoration from fallen leaves, plant pruning, and decaying roots eventually reaches equilibrium, with little or no net change in soil OC. Similar trends have been observed in both temperate and tropical agricultural systems. In the studied schemes most tea farms were more than 30 years old, therefore the accumulation of litter on soils increased organic matter in the soils.

5.2.4 Cation exchange capacity

The CEC results of the study sites are summarized in Table 1 and Table 2. According to Kimambo and Lupembe, (2010), all farms fell below the optimum level of (15-25 Cmole/kg), its implying that all farms had a low CEC most likely due to the nature of the mineral clay which was dominated by Kaolinite, This mineral clay have very low to low natural fertility (Melliyo and Hiza, 2006). Also low CEC could be due to leaching of bases accelerated by the high acidity levels example soils with pH around 4.18. Some farms had high percentage of sand which is more than 50 percent; this sand had small surface area contributing direct to lower soil CEC compare with soils with high percent of clay content. Most tea farms in Lushoto district found in slopes range from 40 to 60 percent (Melliyo and Hiza, 2006), these farms were suffering from erosion which had negative effect to soil fertility. The CEC value used as an estimate of the ability of soil colloids to attract, retain and exchange cation site with positive charges (Including Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} and NH_4^{+}

5.3 Soil macro nutrients

5.3.1 Total Nitrogen

The results of total N for the soils under study are summarized in Table 1 and Table 2, According to Kimambo and Lupembe, (2010) soils are categorized as deficiency < 0.25%N. Other workers in tea growing soils obtained similar results (Ranganathan and Narayanan, 1975; Ndunguru, 2003). The results in study area imply that most farmers do not apply fertilizers as N source in their farms, therefore low levels of N could be attributed to nutrient mining by continuous tea harvesting without additions of N fertilizers. Othieno (1992) reported low levels of total N was due to nutrient mining as a result of frequent plucking of the tender succulent shoots where about 40 kg N is removed from the soils for every 1000 kg of made tea produced.

5.3.2 Available phosphorus

The Bray-1 extractable P for the soils are show in Table 1 and Table 2. Based on kimambo and Lupembe, (2010) available P was in deficiency < 10 Cmole/kg soil in study area. This finding was similar to previous studies in Available phosphorus by Udo and Uzo, (1972); Othieno, (1992), the observed P levels in the study area were very low and cannot support high tea production. Low tea yields reported in study area might be partly contributed by this problem. In all schemes there was P deficiency due to most farmers do apply Phosphate fertilizers or rock phosphate to adequate quantities. Presence of free iron or aluminum or manganese in some fields causes a fixation of phosphate. Continued nutrient mining through harvesting of tea crop for long time without replenishment of P may further account for the observed low P levels and it is estimated that 2000 kg made tea/ha removes between 4 and 5 kg P/ha/year from the soils. Loss of P through leaching is virtually none existing because of its low mobility (Othieno, 1992). Phosphorus availability in tropical soils is influenced by pH and the presence of free iron or aluminum or manganese (Cordingley, 2010) as well availability of P is pH dependent and high available at pH between 5.5 and 7.0 (Bhattacharya and Dey, 1993). In contrast Zoysa *et al.*, (1997) comment that in New *Zealand,* despite the high P fixation in acidic soils, tea plants do not generally suffer from P deficiencies because they have some mechanisms by which they are able to utilize the fixed P in soils. Earlier studies on camellia (*Camellia japonica* L.) plants of the same family as tea showed that plant roots can modify the root environment by acidifying the rhizosphere and may release organic compounds which can enhance the utilization of P. Application of P containing fertilizers such as TSP, NPK and use of locally available low cost phosphate rocks such as Minjingu phosphate rock suited to acidic soils due to greater solubility of phosphate rock at low pH levels, is necessary in order to increase and sustain high levels of tea production.

5.3.3 Potassium

The exchangeable K in the soils are presented in Table 1 and Table 2. According to the guide by Kimambo and Lupembe, (2010) all farms had low K level. Generally low nutrient content of the soil indicated that the soil could not be cropped for long without fertilizer application for optimal tea growth and performance. K deficiency may be due to the nature of the parent material and clay minerals: kaolinite in a soils were dominated in the study areas, soil pH were strongly and very strongly acid all these affect K availability. K^+ is highly leaching out of root zone in soils. Othieno (1992) the harvestable tea crop contains an average 1.75 to 2.00 percentage K on a dry weight basis which works out to between 35 and 40 kg K $ha^{-1}$and between 87.5 and 100 kg K ha^{-1} removes each year for tea yielding 2000 and 5000 kg made tea $ha^{-1}year^{-1}$ respectively.

5.3.4 Available Sulphur

The exchangeable sulphur (S) in levels in study area are summarized in Table 1 and Table 2. According to Kimambo and Lupembe, (2010), farms in study area had optimal level of soil S (3.0- 4.0). This result in contrast to Tandon, (1995) say, generally in agricultural of humid and sub-humid regions S ranges from 0.01 to 0.05%. Kamasho and Singh, (1980) working in Tukuyu reported dominancy of basalt rocks which were found to contain about 0.07% of Sulphur. These rocks are found throughout the Lushoto district and might be one of the sources of S to the soils, (Harkin, 1960).

5.3.5 Magnesium

The exchangeable Mg levels in the study area indicated in Table 1 and Table 2. According to kimambo and Lupembe, (2010) Mg in soils was within the optimal level of (3.0 - 4.0). This finding is in contrast to Othieno (1981) who found, Mg was 1.52 therefore below soil critical value of 3.3 Cmol/kg. Studies by Mhosole, (1995) revealed low exchangeable Mg content in the tea growing soils of Mufindi, Kitundu (2001) also found low to medium exchangeable Mg content in tea growing soils of Kibena estates in Njombe.

In this study some farms recorded Mg levels below the critical value. Generally low Mg content of the soil indicates that the soil could not be cropped for long period of time without Mg fertilizer application for optimal tea growth and performance. The deficit of this element may be due to parent material from which soils originated, leaching losses, low pH values in most tea farms, Mg replaced by Fe, Mn and Al^{3+} on soil colloids. Some farms had inadequate Mg which required by tea plant for photosynthesis therefore, could be a limiting factor in attaining potential yield. The significantly lower level of exchangeable Mg in some farm tea soils was possibly a result of depletion through the continuous harvesting of young shoots for tea products and/or increased leaching due to soil acidification without sufficient repletion with fertilizers.

5.3.6 Calcium

The results on Ca levels are shown in Table 1 and Table 2. According to Kimambo and Lupembe, (2010) most farms were rich with Ca above (1.0 - 2.0 Cmole/kg). In other hand, with some few farms were Ca indicated deficient of Ca could not be cropped for long period of time without Ca fertilizer application for optimal tea growing and performance. Low Ca could have been a result of high levels of Al, Fe, Mn and low pH facilitating leaching of Ca may result to leach Ca. The range show clearly the big variation in top soils, calcium across the sampled areas, this variation could be due to a function of cation exchange capacity on soil texture, where heavier soils of relatively high clay content, contained much more calcium than the soils which had a higher sand content.

5.4 Some micro nutrient elements in soils

5.4.1 Zinc

The amount of extractable Zn is presented Table 1 and Table 2. According to Kimambo and Lupembe, (2010) categories the levels of Zn, all soils in tea farms were below optimal level (15.0-20.0 ppm). The results correspond to those of Ndunguru, (2003) who reported low level of Zinc. Low zn levels in soils of southern Tanzanian may be due to the nature of soil parent material, both primary and secondary minerals were deficiency in Zinc. Zinc is not readily absorbed by tea from soil and its deficiency is not readily corrected by ground application of Zinc compound. Foliar application is very effective. The application of Zn as Zinc oxide is advisable at rates of 4.5 kg /ha/year the small quantity of zinc in the plant makes it desirable to repeat the treatment at close interval. Zinc is an important measure to improve productivity and cup quality of tea (Ruan and Härdter, 2001).

5.4.2 Copper

The amounts of extractable Cu are presented in Table 1 and Table 2. Kimambo and Lupembe, (2010) suggested that for normal plant growth, the critical limit for Cu should be (10ppm) all soils in tea farms were below 10 ppm. Similar findings were reported by Kamasho and Singh (1980) and Ndunguru (2003) low levels of Cu in study area occur may be due to the nature of mineral clay which was Kaolinite which is deficient deficiency in Cu. Copper is an important for tea constituent of the enzyme polyphenol oxidase, which is vital for fermentation of tea (Bonheure and Willson 1992).

5.4.3 Iron

The available Fe contents of soils are presented in Table 1 and Table 2. According to Kimambo and Lupembe, (2010) all soils in tea farms, were almost in optimal levels (above 10 ppm). The result is concurrent with that of Ndunguru (2003). Iron is usually freely available in acid soils so deficiencies are uncommon although they are likely to occur in soil at the upper pH range. Fe is important for various chemical processes within the tea that improve production and quality, Othieno, (1992). It is a constituent of many enzymes and is catalyst for respiration, photosynthesis and reduction of sulphates and nitrates. It also plays part in the formation of chlorophyll

5.4.4 Manganese

The amount of extractable Mn is presented in Table 1 and Table 2. Kimambo and Lupembe, (2010) suggested the critical limit of Mn as 10 ppm. On average, the farms had adequate amount of Mn, Usually Manganese is available in acid soils. Low pH of the soils favors the dissolution of Mn compound (Alloway and Ayres, 1990). In tea Manganese is associated with Iron in the formation of chlorophyll and act as a catalytic in some processes in the metabolism of the tea so it contribute in yield and quality of tea (Othieno,

15.5 Soil physical analysis result

5.5.1 Soil texture

Soil texture Soil texture analyses results are tabulated according to schemes followed by overall mean values for four schemes in Lushoto district Table 1 and Table 2. These results had interpreted that; Balangai scheme textural class was Loam and Mponde scheme Sandy Loam to Loam. Bumbuli scheme textural class was Sandy Loam and Mazumbai scheme textural class was Sandy Loam. The textural classes of soils in farms of study areas were generally under the same broad textural class known as Loam; which is sandy loam, silt loam and loam. These soils were suitable for tea production (Othieno, 1992).

5.6 Chemical analysis results of third leaf

5.6.1 Nitrogen

The contents of N in the third leaves of tea plants are shown in Table 3 and Table 4. According to kimambo and Lupembe, (2010) nitrogen level is categorized as deficient if N <2.5%. The results are contrast with Verma, (1997) who found that third leaf contains at 3.5 up to 5% N on dry matter basis in production of tea. Based on this critical limit, the mean values for all the schemes fall in deficient range, corresponding to low N in the soils due to inability of farmers to apply N containing fertilizers and lack of organic amendments, might be the cause of low N in tea plants. This calls for replenishment through application of N containing fertilizers and organic amendments such as the use of tea wastes from nearby tea processing plants and use of wattle and paper sludge where available

5.6.2 Phosphorus

The content of P in third leaves of tea plants are shown in Table 3 and Table 4. Kimambo and Lupembe, (2010) Categorize P for the third leaf of tea plant (0.3-05% as optimal level). The result suggest that on average, tea plants had optimal level of P. Compared to Verma and

Venkatesan, (2001) point out that tea flush shoots contain 0.24-0.32% P and hence a tea field yielding around 3000 kg of made tea per hectare per annum remove approximately 7 to 10 kg of phosphorus every year. In contrast to other information, Bonheure (1990) who found that the normal P concentration of the flush shoots was between 1.8 and 3.9% of dry matter, and the critical. P concentration was below 1.8%. The results in study area indicate that all schemes mean values had optimal level of P may be the reason was that despite the P fixation in some soils, tea plants do not generally suffer from P deficiencies to some extent because, tea plants have some mechanisms by which they are able to utilize the fixed soil P. Earlier studies on camellia (*Camellia japonica* L.) plants, which is of the same family as tea, revealed that plant roots can modify the root environment by neutralize the rhizosphere and may release organic compounds which can enhance the utilization of P (Zoysa *et al.*, 1997).

5.6.3 Potassium

The content of K in the third leaves tea plant is shown in Table 3 and Table 4. According to Kimambo and Lupembe (2010) these results advocated that tea plants in study area were in optimal level (2.00 - 5.00%). This result in contrast to Ndunguru, (2003) who found out that K in the third leaf range from 1.22 and 2.81%, the leaf had enough K probably due to its high mobility in plants and also, its uptake by plants is highly selective and closely coupled to metabolic activity. Potassium is the second major nutrient for tea after N and makes up 2-5% of the dry matter in tea leaves (Verma, 1997, 1993; Wu Xun *et al*.1997).

5.6.4 Sulphur

The S content of the third leaves of tea shoots are summarized Table 3 and Table 4. This result, in contrast to Ndunguru, (2003) who found that the third leaf range from 0.07 to 0.25% of S. Soil and foliar application of S can solve the deficiency in the observed problem areas.

The harvestable crop contains between 0.15 and 0.20% of sulphur on dry weight basis (Othieno, 1992). The compound fertilizers used in tea contain sulphur NPKS, (25:5:5:5) therefore the deficiency is not always encountered except in isolated

5.6.5 Calcium

The contents of Ca in the third leaves tea plants are shown Table 3 and Table 4. According to Kimambo and Lupembe (2010) on average tea plants in study area had excess Ca concentration in their third leaf. This result in contrast to Ndunguru, (2003) who found that the third leaf range from 0.13 to 0.45% of Ca in Rungwe district Tea growing area.

5.6.6 Magnesium

The contents of Mg in third leaves tea plants are shown in Table 3 and Table 4. Based to kimambo and Lupembe, (2010) these results put forward that on average tea farms were in (optimal level 0.2 - 0.4%) the results compared to Wu Xun *et al.,* (1997) who found Magnesium content in third leaf was 0.30% of the leaf dry matter. Opposing to this level found in study area magnesium deficiencies widely occur in the tea plantation regions mainly due to the higher leaching as well as the higher demands (Verma, 1997, Wu Xun *et al.*, 1997). On average, the harvestable tea crop contains between 0.05 and 0.25% Mg on dry weight basis (Othieno, 1992)

5.7 Micronutrients in third leaf of tea plants

5.7.1 Copper

The Cu in concentration in tea third leaf of tea plants is presented in Table 3 and Table 4. Kimambo and Lupembe, (2010) reported the critical level of Cu in the tea third leaf to be (20ppm) In view of this critical limit all scheme mean values were below the optimal level these advocate that due to attributed to low level of copper in soils. High levels of Iron in the soils may also induce Cu deficiency (Landon, 1991), also poor management in crop husband, especially farmers they don't apply Cu in their field, through foliar application as a Copper oxide, (example Copper oxide in rate of 4.5 kg/ ha/year). The role of copper in tea leaves is an essential constituent of the enzyme polyphenol oxidase, which is vital for fermentation (Bonheure and Willson 1992).

5.7.2 Manganese

The concentrations of Mn in the third leaf are presented in Table 3 and Table 4. Kimambo and Lupembe, (2010) categorized the Mn contents in the third leaf of tea shoots (in optimal levels 100-400 ppm) in view of these categorization of farms in the study area falling under the excess. This result was in contrast to Ndunguru, (2003) point out that the third leaf range from 80 to 1497 mg/kg. Acidity of the soils under the study area might have contributed to high availability of Mn to tea plants. It was estimated that principal species in solution Mn which is Mn^{2+} increase 100-fold for each unit decrease in pH (Tandon, 1995). Furthermore, Mn in leaves was higher because soil organic matter in soils improve the uptake of Mn probably this may be due to the litter effect when the amount of SOM increase in soils after decomposition release Mn readily available to plants. Furthermore, low pH improves the uptake of Mn.

5.7.3 Zinc

The concentration of Zn in third leaf tea plants are shown in Table 3 and Table 4. According to kimambo and Lupembe, (2010) on average, most tea plants had the optimal level (15.0-20.0). This result compared to Ndunguru, (2003) who found out that the third leaf range from 11 to 50.4 ppm. Zinc is an important measure to improve productivity and quality of tea (Ruan and Härdter, 2001).

5.7.4 Iron

The concentration of Fe in the third leaf tea plants was shown in Table 3 and Table 4. According to kimambo and Lupembe (2010) Reported as an (optimal level of iron 5.0-10.0 ppm), these findings in contrast to Ndunguru, (2003) point out that the third leaf range from 35.2 to 202.4 ppm. The results in a study area suggest that most farms in schemes were above optimal level of iron the these implies that low pH influence the availability of iron therefore, low pH values improve the uptake of Fe as a results increases the accumulation of Fe in leaves

5.8 Yield results; on station experiment

The dried tea yields mean results during the short rain season are summarized in Table 5. Nitrogen fertilizer responses, results show treatment 280 kg N/ha had highest yield (1502 kg/ha). The lowest yields were obtained from the control 0 kg N/ha with yield of 796 kg/ha. The mean yield obtained across the treatments 160, 200, 240, 280 kg N/ha, were no significant different. These results implies that in order to attain reasonable yield in short rain seasons, applications rates of 160 kg N/ha in contrast to blanket recommendation rate of TRIT 150 kg N/ha, may be these variation happen because of various reasons such as the degree of soil fertility depletion in tea farms, low soil moisture content in soils during short rain season, water which act as a solvent on fertilizers in soils to improve solubility of fertilizer so that to release nutrients in form of solution ready taken by plant roots. On responses of clones the clone 207 had the lowest yield (803 kg/ha). Clones K 35, K 7 and 282 were no significant different in mean yield 1381b, 1323b and 1491b kg/ha respectively, However, these results show that among the three clones 282 was considerably the highest yield, this could be due to its drought tolerance to adverse weather condition in addition to genetic variation among these tea clones may result in variation in yields which are not directly influence by N application.

The dried tea yields results for the long rain season are reported table 4. Treatment 280 kg N/ha (N_7) had highest yield (2996d kg/ha) which was significantly different from control (0 kg N/ha, Yield 1263a), there were no significant different among these treatments N_3 - N_7 (1252bd, 1351bd, 1388cd, 1466cd and 1502d), these results implies that during the long rain seasons, generally it is possible to apply 120 kg N/ha compared to short rain season which were 160 kg N/ha, these findings having the range of 120 – 160 kg N/ha, contrasting to blanket recommendation by TRIT which are 150 kg N/ha. These variations may be due to residual effect of fertilizer applied on short rain season. Furthermore, high moisture content in soils during the long rain season could have provided a favorable conditions for tea growing such as increase the solubility of plant nutrients consequently increases both water and plant nutrients up take by roots of tea plant.

On responses of clones to nitrogen fertilizer, the results suggest that clone 207 had highest yield (2964 kg/ha) which was significant different with that of clones K 7, K 35 and 282. Clone K 7 had the lowest yield (2079 kg/ha). However, clone 282 and K 35 were no significant different in terms of yield (mean yield 2392 and 2614kg/ha). These results put forward a suggestion with adequate soil moisture clone 207 perform highly compared to short rain season, may be due to genetically variation among the clones.

Tea yield during long rain season were doubled compared with short rain season (Table 5 and 6 Grand mean 1250 kg/ha for short rain and 2512 kg/ha for long rain season) these results implies that differences in yields may be attributed with adequate soil moisture content during the long rain season..

The Annual mean yield results of dried tea for rates of nitrogen fertilizer and four clones are presented in Table 7. On nitrogen rate responses, the results show that treatment 280 kg N/ha

(N_7) had overall highest yield 4539 kg/ha and significant differences to control (0 kg N/ha) 1984 kg/ha. Treatments 120, 160, 200, 240 and 280 kg N/ha (3946cd, 4159cd, 4309d, 4442d and 4539d) were no significant differences, generally the results show that 120 kg N/ha this rate is advisable to use in tea farms, because the yield given in this rate does not differ statically compared to 160, 200, 240 and 280 kg N/ha. Also in terms of economic. Responses of clones to nitrogen fertilizer, the yield trend indicate that clones 282 had highest yield of 4288 kg/ha, followed by clone K35, no significant differences between the two. Also clone K7 had lowest yield of 3299 kg/ha significant differences with clone 207, the results imply that clone 282 and K 35 were high yield, perhaps clones were moderately susceptible to drought throughout the year, clone 207 and K 7 were low yield probably, because were susceptible to drought/adverse condition during short rain.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study was carried out with the aim to evaluate soil fertility status smallholder tea farms and fertilizer use in Tanga region, Tanzania. The study also assessed the response of four clones to the application of Nitrogen at eight rates

The following conclusions can be drawn:

- The soil macro nutrients elements especially Total Nitrogen, Available Phosphorus and Potassium were deficient.
- Soil micro nutrients elements in particular Zn and Cu were also deficient contributing to low tea yields.
- Soil Cation Exchange Capacity was below optimal level.
- Third leaf test macro nutrients Nitrogen was below the optimal levels and micro nutrients Copper was below the optimal level contributing to low the yields.
- During the short rain season: clones K 35, K 5 and 282 at N application of 160 kg N/ha yielded the best.
- In the long rain season; clone 207 at N rate of 120 kg N/ha yielded the best.
- The annual mean yield indicates that two clones were superior; K 35 and 282 together with N application rates at 120 – 160 kg N/ha

5.2 RECOMMENDATIONS

5.2. Recommendations

Based on results of this study, it is recommended that;

- Nitrogen nutrient (120 – 160 kg N/ha) should be applied in tea farms of smallholders to increase yield tea in four schemes in Lushoto district, Tanga.

- Clones K 35 and 282 should be used in smallholder farms in four schemes in Lushoto district.

Recommendation for further research; to conduct research on different rates of P and K on tea clones

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APPENDICES

Appendix I: Experimental layout of the study in Marikitanda Tea Research Station Tanga

K 7	89 7	90 0	91 3	92 6	93 5	94 1	95 2	96 4
	81	82	83	84	85	86	87	88
207	2	5	0	6	3	4	1	7
K 35	73 6	74 0	75 2	76 5	77 7	78 4	79 3	80 1
282	65 1	66 2	67 5	68 7	69 3	70 0	71 4	72 6

↕ 3m

282	57 1	58 5	59 2	60 3	61 7	62 0	63 6	64 4
K 7	49 2	50 4	51 6	52 1	53 0	54 3	55 7	56 5
207	41 0	42 1	43 3	44 2	45 6	46 7	47 5	48 4
K 35	33 1	34 5	35 7	36 4	37 0	38 3	38 2	40 6

207	25 0	26 1	27 2	28 6	29 7	30 3	31 4	32 5
282	17 4	18 3	19 0	20 5	21 6	22 2	23 7	24 1
K 7	9 7	10 5	11 3	12 2	13 4	14 6	15 0	16 1
K 35	1 0	2 5	3 2	4 1	5 7	6 4	7 3	8 6

KEY: In black color: Treatments;. 0 = 0kgN/ha, 1 = 40 kgN/ha ; 2 = 80 kgN/ha, 3 = 120 kgN/ha, 4 = 160 kgN/ha, 5 = 200 kgN/ha, 6 = 240kgN/ha.7 = 280kgN/ha In red color: Plots number

Appendix II: An outline of Analysis of variance (ANOVA) used in statistical analysis

1. The dried tea yields mean results on rates of nitrogen fertilizer and four clones during short rain season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	154382.	77191.	1.39	
Clone	3	6725589.	2241863.	40.38	<.001
N_Level	7	4606842.	658120.	11.85	<.001
Clone.N_Level	21	595740.	28369.	0.51	0.956
Residual	62	3442552.	55525.		
Total	95	15525105.			

II. The dried tea yields results on rates of nitrogen fertilizer and four clones during long rain season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2075855.	1037927.	5.04	
Clone	3	9999699.	3333233.	16.19	<.001
N_Level	7	27966214.	3995173.	19.41	<.001
Clone.N_Level	21	1853392.	88257.	0.43	0.983
Residual	62	12763097.	205856.		
Total	95	54658256.			

III. The Annual mean yield results of dried tea for rates of nitrogen fertilizer and four clones

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Rep stratum	2	3284505.	1642252.	6.26	
Clone	3	4106611.	1368870.	5.22	0.003
N_Level	7	60342248.	8620321.	32.87	<.001
Clone.N_Level	21	2819906.	134281.	0.51	0.955
Residual	62	16258418.	262233.		
Total	95	86811688.			

Appendix IIIA: Guide for the interpretation of soil analytical results (TRIT)

Soil parameters / Levels	**pH** (H_2O)	**TN** (%)	**OM** (%)	**P**	**S**	**Mg**	**Ca**	**K**	
Excess	>6.5	>0.8	>7.5	>30	>6	>6.0	>6.0	>3.0	
Optimum range	5.0-5.6	0.3-0.5	3.0-5.00	20-25	3.0- 4.0	3.0-4.0	1.0-2.0	1.0-2.0	
Deficiency	< 3.8	<0.2	< 0.5	<10	<0.2	<0.5	<0.5	<0.5	
Soil parameters / Levels	**CEC**	**Cu**	**Fe**	**Mn**	**Zn**	**Al**	**%SAND**	**%SILT**	**%CLAY**
Excess /toxic	>40	>28	>60	>100	>40	>30			
Optimum range	15-25	10-15	10-20	45-55	15-20	20-30	40	40	20
Deficiency	<10	<2	<1	<10	<10	<10			

KEY: P and S in (mg/kg) Mg, Ca, K and CEC in me/100g. Cu, Fe, Mn, Zn and Al in ppm

Appendix IIIB: Guide for the interpretation of third leaf analytical results

Leaf parameter / Levels	**N (%)**	**P (%)**	**Ca (%)**	**K (%)**	**Mg (%)**	**S(mg/kg)**
Excess	>8	>0.8	>7.00	>8.00	>1	>6
Optimum range	2.00-5.00	0.3-0.5	0.2-5.00	2.00-5.00	0.2-0.4	0.3-0.5
Deficiency	<1.00	<0.1	<0.1	<1.0	<0.05	< 0.1
Leaf parameter / Levels	**Zn** (ppm)	**Cu** (ppm)	**Fe** (ppm)	**Mn** (ppm)	**Al** (ppm)	
Excess	>40.00	>30	>70	>100	>633	
Optimum range	15.0-20.0	20-25.	5.0-10.0	15.0-20.0	20-40	
Deficiency	<10	<2	<1	< 12	<25	

Appendix IV: Initial soil test for fertility status of study area for MTRS in on station

Plot No.	pH (H_2O)	pH (KCL)	N(%)	P	K^+	Ca^{2+}	Mg^{2+}	CEC	OC(%)
	(1:2.5)	(1:2.5)		(Cmole/kg)	**Exch.Bases** (Cmole/kg)			(Cmole/kg)	
1	6.03	4.83	0.15	13.49	0.58	5.320	0.80	6.80	1.71
2	6.16	4.89	0.13	13.20	0.60	5.216	0.81	9.71	3.71
3	6.10	4.86	0.14	13.34	0.59	5.27	0.80	8.26	2.71
4	5.91	4.71	0.16	8.27	0.61	6.093	0.75	8.78	3.23
5	5.93	4.68	0.17	20.02	0.53	6.010	0.85	9.23	2.16
6	5.92	4.70	0.17	14.14	0.57	6.05	0.80	9.01	2.70
7	5.37	4.23	0.21	15.59	0.56	3.719	0.62	13.79	3.56
8	5.45	4.29	0.20	9.72	0.50	4.950	0.79	12.06	3.68
9	5.41	4.26	0.21	12.66	0.53	4.33	0.71	12.93	3.62
10	5.00	4.19	0.13	9.50	0.44	3.510	0.68	9.71	1.94
11	5.44	4.24	0.14	11.02	0.41	2.809	0.47	7.90	3.39
12	5.22	4.22	0.14	10.26	0.42	3.16	0.58	8.81	2.67
13	5.22	4.08	0.15	21.03	0.39	4.255	0.95	9.63	2.22
14	4.99	4.09	0.15	5.58	0.37	4.805	0.94	10.43	2.16
15	5.11	4.09	0.15	13.31	0.38	4.53	0.94	10.03	2.19
16	5.79	4.82	0.16	12.76	0.91	6.236	1.44	10.10	3.92
17	5.86	4.84	0.19	12.76	0.83	12.659	1.43	9.09	2.17
18	5.83	4.83	0.18	12.76	0.87	9.45	1.43	9.60	3.05
19	5.92	4.97	0.21	5.29	0.73	11.375	0.99	8.96	2.10
20	5.95	5.00	0.14	4.13	0.80	14.140	1.41	9.18	2.09
21	5.94	4.99	0.18	4.71	0.77	12.76	1.20	9.07	2.10
22	5.65	4.59	0.13	12.26	0.92	9.743	1.26	7.82	1.78
23	5.56	4.59	0.13	11.60	0.89	9.044	1.30	8.35	1.81
24	5.61	4.59	0.13	11.93	0.90	9.39	1.28	8.09	1.80
25	5.33	4.37	0.13	5.87	0.74	7.621	1.04	7.76	1.87
26	5.35	4.36	0.12	12.47	0.71	5.540	0.78	7.68	1.75
27	5.34	4.37	0.13	9.17	0.72	6.58	0.91	7.72	1.81
28	5.33	4.44	0.15	13.42	0.60	10.905	1.39	9.12	1.94
29	5.37	4.45	0.14	5.66	0.56	10.698	1.34	8.78	1.86
30	5.35	4.45	0.15	9.54	0.58	10.80	1.37	8.95	1.90

31	5.47	4.39	0.16	22.70	1.64	7.929	1.30	9.18	2.15
32	5.40	4.42	0.16	20.89	1.43	8.754	1.33	7.74	2.30
33	5.44	4.41	0.16	21.79	1.54	8.34	1.31	8.46	2.23
34	5.17	4.22	0.17	11.82	1.33	6.542	0.96	9.01	2.23
35	5.17	4.23	0.17	10.01	1.13	7.295	1.14	7.98	2.15
36	5.17	4.23	0.17	10.91	1.23	6.92	1.05	8.50	2.19
37	5.46	4.52	0.19	5.58	1.64	13.106	1.36	8.11	2.62
38	5.49	4.53	0.19	5.87	1.64	12.198	1.42	9.14	2.34
39	5.48	4.53	0.19	5.73	1.64	12.65	1.39	8.63	2.48
40	5.30	4.52	0.17	9.57	1.54	12.015	1.32	7.70	2.28
41	5.39	4.53	0.18	11.60	1.64	10.829	1.33	8.45	2.50
42	5.35	4.53	0.18	10.59	1.59	11.42	1.32	8.08	2.39
43	5.32	4.46	0.16	25.38	1.23	12.878	1.74	8.43	2.22
44	5.33	4.48	0.16	25.75	1.23	13.594	1.70	7.92	2.18
45	5.33	4.47	0.16	25.56	1.23	13.24	1.72	8.18	2.20
46	5.62	4.59	0.15	12.33	1.13	12.185	1.62	7.60	1.94
47	5.63	4.55	0.15	13.13	1.13	11.697	1.40	7.73	1.99
48	5.63	4.57	0.15	12.73	1.13	11.94	1.51	7.67	1.97
49	5.73	4.76	0.13	8.85	0.92	15.822	1.75	8.00	1.91
50	5.80	4.78	0.15	9.28	0.82	14.287	1.63	7.47	1.92
51	5.77	4.77	0.14	9.07	0.87	15.05	1.69	7.74	1.92
52	5.86	4.77	0.13	6.38	0.82	14.698	1.66	7.31	1.70
53	5.86	4.75	0.13	9.36	0.72	14.802	1.64	7.66	1.72
54	5.86	4.76	0.13	7.87	0.77	14.75	1.65	7.49	1.71
55	5.58	4.51	0.14	5.87	0.61	11.936	1.29	8.03	2.06
56	5.56	4.61	0.15	6.60	0.61	15.492	1.54	7.90	1.91
57	5.57	4.56	0.15	6.24	0.61	13.71	1.41	7.97	1.99
58	5.24	4.34	0.18	18.71	0.61	11.544	1.66	8.46	2.19
59	5.18	4.30	0.17	22.12	0.72	9.464	1.03	7.17	1.87
60	5.97	4.67	0.82	13.45	1.35	5.830	1.40	7.16	1.39
61	5.83	4.19	0.37	7.93	1.27	12.750	1.59	7.55	1.31
62	5.48	4.31	0.23	11.45	1.45	5.980	1.60	7.54	1.73
63	5.57	4.91	0.52	10.34	1.87	9.530	1.50	7.90	1.49
64	5.21	4.21	0.82	9.35	1.56	4.840	1.85	7.50	1.94
65	5.64	4.54	0.21	12.48	0.21	7.820	1.94	8.52	1.60
66	5.92	4.37	0.63	13.56	0.54	12.500	1.62	8.50	1.28
67	5.32	4.39	0.29	15.28	1.82	5.98	1.37	8.19	1.41
68	5.64	4.92	0.44	9.37	0.95	8.50	1.59	8.41	1.05
69	5.92	4.31	0.85	7.35	0.53	10.55	1.41	8.94	1.69
70	5.05	4.71	0.41	13.55	0.85	12.67	1.85	8.51	1.21
71	5.21	4.62	0.64	9.45	0.72	11.80	1.80	7.29	1.16

72	5.41	4.51	0.83	6.35	0.94	8.15	1.41	8.51	1.64
73	5.97	4.63	0.39	12.85	0.27	8.41	1.90	8.94	1.73
74	5.25	4.64	0.63	9.50	0.55	12.00	1.52	8.27	1.83
75	5.28	4.72	9.85	9.98	1.50	7.43	1.83	7.49	1.09
76	5.79	4.97	0.94	13.52	1.52	9.74	1.26	7.29	1.74
77	5.82	4.38	0.48	12.55	1.70	13.32	1.48	7.50	1.86
78	5.40	4.86	0.63	14.56	1.58	10.63	1.29	7.91	1.52
79	5.47	4.36	0.59	12.52	1.51	7.31	1.71	7.49	1.74
80	5.39	4.93	0.55	7.43	0.55	8.58	1.25	7.65	1.63
81	5.32	4.94	0.75	9.34	0.72	11.55	1.93	7.85	1.73
82	5.9	4.62	0.95	13.34	0.48	14.26	1.44	7.90	1.93
83	5.90	4.82	0.23	7.19	1.82	9.41	1.55	8.46	2.00
84	6.92	4.91	0.39	8.26	1.23	14.29	1.98	8.37	1.83
85	6.54	4.87	0.73	9.48	0.82	8.38	1.31	8.35	1.28
86	6.73	4.63	0.29	11.39	0.73	8.92	1.42	8.31	2.91
87	6.29	4.92	0.74	9.38	0.26	13.91	1.94	8.69	2.48
88	5.93	4.85	0.73	8.38	0.62	8.31	1.62	8.41	3.04
89	6.83	4.24	0.63	9.67	0.62	7.37	1.62	8.32	2.11
90	6.29	4.23	0.63	11.74	1.38	11.26	1.96	7.00	1.79
81	6.41	4.63	0.74	9.51	1.91	14.39	1.13	7.92	2.31
92	5.39	4.25	0.41	9.62	0.17	11.02	1.37	7.35	1.38
93	4.66	4.75	0.52	9.03	0.92	13.82	1.82	7.28	1.37
94	5.74	4.62	0.85	10.45	1.72	12.39	1.93	7.24	1.28
95	6.43	4.04	0.19	12.48	1.38	9.27	1.29	7.27	1.39
96	6.12	4.92	0.51	12.55	1.94	9.73	1.64	8.05	1.74

Appendix V: The list of farmers, village, Tea yields and schemes where soils and leaf samples were obtained

The Soil and leaf samples were collected from BALANGAI, MPONDE, BUMBULI, and MAZUMBAI SCHEMES for assessment of soil fertility status in smallholder tea farms of Lushoto district, Tanga region, the total samples were 104 (52 soil and 52 leaf samples).

The following information obtained in field such as 1.Soil sampling number (SS) and leaf number (LS) 2.Name of farmer 3. Schemes/ Village 4. Elevation 5.Soil depth was 30cm for all soil samples and third leaf for all leaf samples. Sampling date 16 . 04 . 2011 for Balangai Schene were total of 36 (soil18 and leaf 18)samples). 17 . 04 . 2011 for Mponde Scheme samples were 38 (soil 19 and leaf 19 samples), 18 . 04 . 2011 for Bumbuli Scheme were14 (soil 7 and leaf 7 samples) and 19 . 04 . 2011 for Mazumbai scheme were 16 (soil 8 and leaf 8 samples)

BALANGAI SCHEME

SS / LS	NAME OF FARMER	VILLAGE	TEA YIELD Kg/mt/ha	ELEVATION Above S-Level (GPS)
1	Muhidin Athumani	Balangai-Sakale	965	1386 -
2	Ramadhani&Malik(U/S)	Kwemilunga village	1043	□
3	Ramadhani&Malik(U/S)	Mkoko Village	1241	1434
4	Binuru Amiri	Sakare Village	1596	1443
5	Isaka Musumba(L/S)	Mkoko village	973	□
6	Isaka Musumba(U/S)	Tamota Nkububu	1532	1463
7	Said Sanondo	Tamota Village	1700	1223
8	Anna Rajabu	Nkelei Mzizima	1439	□
9	Rajabu Mhenga	Makoko	963	□
10	Bakari Banda	Makoko	1654	
11	Mwinjuma Hassan	Ngwelo village	1686	□
12	Hamis Sebarua	Ngwelo villace	1563	1330
13	Paulo Dafa	Tamota village	1434	□
14	Dastun Raphael(U/S)	Tamota village	1173	1351
15	Datsun Raphael(L/S)	Tamota village	1339	1348
16	MamaNusura	Mpalalu village	1727	1330
17	AthumanShemkwa(L/S)	Mpalal uvillage	1646	1423
18	Said Soki	Kwemilunga village	1640	□

MPONDE SCHEME

SS / LS	NAME OF FARMER	VILLAGE	TEA YIELD (Kg/mt/ha)	ELEVATION Above S-Level (GPS)
1	AbdalahKusaga(u/s)	Mahange Murai	1548	□
2	Jabili Hasan	Mahanje Mulesa	1125	1314
3	Rajabu Rashid	Mahanje Mulesa	874	□
4	Kupoza Mgaa(L/S)	Kwemuhafa	1374	371
5	Simon Mwakalukwa	Kwemuhafa	1054	□
6	Simon Mwakalukwa	Nkamai	973	1378
7	Daudi Shedafa	Nkemai	1563	1398
8	Ramadhani Faraga	Kweminyasa	1147	□
9	Fedrik Shemndolwa	Mponde	1572	1322
10	Raphael Shelukindo	Kwemunyasa	1483	1513
11	K.K.K.T	Kweshangalawe	973	1531
12	Shamba la Nyerere(U/S)	Kweminyasa	741	1383
13	Mpilili Family	Kweminyasa	1611	□
14	Shamba la Nyerere	Kweminyasa	862	1565
15	Amiri Juma	Kweminyasa	1051	1561
16	Mama Kado	Tekwa	1372	1525
17	Walesi Nyashi	Tekwa	961	□
18	Esica Abdala	Magilla village	1527	□
19	Rajabu Abdala	Magilla village	1384	□

BUMBULI SCHEME

SS / LS	NAME OF FARMER	VILLAGE	TEA YIELD (Kg/mt/ha)	ELEVATION
1	Kwehangala (U/S)	Kwehangala village	1528	1575
2	Kwehangala (L/S)	Kwehangala village	841	375
3	Kwehangala Farm	Kwehangala village	793	1214
4	Kishashao	Dule village	1205	1311
5	Abas Sheshe	Baga village	1185	1486
6	Amini Hussein	Baga village	790	1678
7	Issa Abed	Baga village	962	1635

MAZUMBAI SCHEME

SS / LS	NAME OF FARMER	VILLAGE	TEA YIELD (Kg/mt/ha)	ELEVATION Above S-Level
1	Abdala Rajabu	Kwabosa	769	□
2	Shaban Singano	Kwavumo block farm	1042	1370
3	Bambileta	Nkongoi village	852	1377
4	Mgwashi sec school	Sagara Village	963	1381
5	Laurent kijazi	Sagara village	772	1378
6	Hilgati Gendo	Mayo Village Buayi	974	1464
7	Halima Mshuza(U/S)	Mayo Village Buayi	1156	1380
8	Peter Dafa(L/S	Mayo village	1190	1385

Appendix VI: Production and Yields of Made Tea by Sector, 1975/76–1999/2000 and 2006/07□2009/10 Tanzania.

PRODUCTION				**YIELDS**			
Estates			**Smallholders**		**Total**	**Estates**	**Smallholders**
Years	**Tons**	**Shares (%)**	**Tons**	**Shares (%)**	**Tons**	**Kilograms per hectare**	
1975/76	10,890	81%	2,614	19%	13,504	1,200	300
1980/81	12,864	84%	2,469	16%	15,333	1,400	400
1985/86	12,050	71%	4,900	29%	16,950	1,300	545
1990/91	13,695	76%	4,397	24%	18,092	1,500	490
1995/96	18,037	91%	1,730	9%	19,767	1,900	190
1998/99	22,473	95%	1,207	5%	23,680	2,368	136
1999/2000	20,074	92%	1,806	8%	21,880	2,115	198
2005/06	22,149	71%	9,199	29%	31,348	1,958	806
2006/07	24,095	69%	10,669	31%	34,764	2,149	932
2007/08	22,094	70%	9,512	30%	31,606	1,970	831
2008/09	22,643	71%	9,430	29 %	32,073	2,019	825
2009/10	21,697	69%	9,949	31%	31,646	1,935	869

Source: Tanzania Smallholders Tea Development Agenc (2011)

NOTE; The calculation of smallholder yields is based on the total smallholder tea area some of which may been abandoned, thus underestimating the true yield.

Appendix VII: Rainfall and temperature data for Mponde Tea Factory Lushoto, Tanga

Year	**2004/2005**			**2005/2006**			**2007/2008**			**2009/2010**		
Month/Year	**Rainfall (mm)**	**Temperature (ºC)**		**Rainfall (mm)**	**Temperature (ºC)**		**Rainfall (mm)**	**Temperature (ºC)**		**Rainfall (mm)**	**Temperature (ºC)**	
	2006	**Max**	**Min**	**2007**	**Max**	**Min**	**2008**	**Max**	**Min**	**2009**	**Max**	**Min**
June	78	22.3	15.6	34	22,1	15.0	179.1	22.1	15.6	111.4	22.6	16.2
July	61	21.4	18.6	76	21.2	15.8	34.1	21.7	14.9	50.6	21.4	14.6
August	59	21.7	17.7	72	21.5	14.7	280.2	22.0	14.6	76.0	21.8	14.8
September	44	23.3	19.4	79	23.1	14.4	30.1	23.2	15.3	5.2	23.6	14.2
October	144	24.5	20.1	109	24.0	15.2	163.5	23.9	15.7	326.9	24.5	16.0
November	13	26.9	21.9	113	25.0	16.9	59.8	25.6	22.6	72.3	25.9	17.0
December	59	28.2	22.8	1	27.1	17.4	67.6	26.6	16.9	224.9	26.4	17.6
	2007			**2008**			**2009**			**2010**		
January	102	28.5	23.1	31	28.0	17.4	44.5	28.0	18.0	170.0	26.8	17.1
February	98	27.4	22.4	16	30.0	20.5	119.0	26.8	16.4	0.0	28.5	17.5
March	132	27.2	22.5	193	27.0	18.0	247.5	26.9	17.5	210.1	28.7	18.2
April	332	25.1	21.6	353	24.6	17.9	481.4	23.9	18.0	435.1	25.6	18.7
May	45	23.8	20.3	282	23.1	16.8	185.4	32.9	16.3	280.3	23.8	18.1
Total Mean	**1165**	**25.0**	**16.4**	**1359**	**24.7**	**18.7**	**1898.2**	**22.6**	**15.5**	**1962.6**	**25.0**	**16.7**

Appendix VIII: Sketch map of schemes under tea production in smallholder farms in Lushoto district