ASSESSMENT OF RESIDUAL EFFECTS OF LONG TERM USE OF NPK: B FORMULATION ON TOBACCO YIELD AND QUALITY IN TABORA REGION

BY

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ABSTRACT

The assessment of residual effect of long term use of NPK plus B formulation on tobacco yield and quality involved soil sampling from four districts; Urambo, Uyui, Tabora and Sikonge. There were two experiments each one with six treatments: pot experiment at ARI Tumbi had three replications while field experiment at Ntalikwa village had four replications. Data collected were; leaf length, green and dry weights grade index and nutrients concentration in plant leaves. The results showed that; total nitrogen was very low (0.03 to 0.18%). Phosphorus was low to medium (5.62 to 60.83 mg/kg soil). Exchangeable potassium was, low to very high (0.06 to 0.81), exchangeable calcium was very low to high (0.01 to 4.4). The cation exchange capacity (CEC) of the soils was low; 6.4 to medium 23.33 me/100 g soil. Tobacco grown in Isenga soils (sandy soils) and Kikungu soils (Alfisols) had good performance in T2 (40.5 mg N kg^{-1}) while Tobacco grown in Mbuga soils (Vertisols) had good performance in T3 (recommended rate 300 mg N kg^{-1}, 238 mg P kg^{-1}, 598 mg K kg^{-1} and 3 mg B kg^{-1} soil). The increase in rates of NPK+B and CAN, Mg, Zn caused death of tobacco in treatments 4, 5 and 6 possibly due to B toxicity. In the field experiment the current formulation, T3 (NPK + B (10:18:24 +0.1 and 5 g CAN) produced below treatment 4, 5, and 6. Dry weight yield and quality increased in treatments with higher rates of NPK+ B formulation with Zn and Mg than the current recommendation. The highest yield was from T6 (2488.12 kg ha^{-1}). Residual nutrients T1 yielded 1411.89 kg ha^{-1} of dry leaf of tobacco. In general, low residual nutrients in Tabora soils need new formulations which include Mg and Zn to improve yield and quality of tobacco.

DECLARATION

I **HUGO GIDO MAPUNDA** do hereby declare to Senate of Sokoine University of Agriculture that the work presented here is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

16/11/2011

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DEDICATION

This work is dedicated to my Lord Jesus, Mary and Joseph the Holy Family who have been my helpers and very dependable friends when I prayed for their support. I also dedicate this work to my parents and my wife who closely supported and encouraged me all the time.

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LIST OF ABBREVIATIONS AND SYMBOLS

ACIAR	-	Australian Centre for International Agricultural Research
AESL	-	Agricultural and Environmental Services Laboratories
ARI	-	Agriculture Research Institute
CEC	-	Calcium Exchange Capacity
DAP		Days after planting
DTPA	-	Diethylene Triamine Pentaacetic Acid
EDTA	-	Ethylenediaminetetraacetic Acid
ETc	-	Evapotranspiration coefficient
FAO	-	Food and Agriculture Organization
FC	-	Field Capacity
FCV	-	Flue Cured Variety
FFTC	-	Food and Fertilizer Technology Centre
GI		Grade Index
MIP	-	Major Intrinsic Protein
MRML	-	Most Recent Mature Leaf Technology Centre
NBPT	-	N – (n-butyl) thiophosphoric triamide
NC	-	North Carolina
NCDA	-	North Carolina Department of Agriculture
NSS	-	National Soil Services
NUE	-	Nitrogen Use Efficiency
pH	-	Potential of Hydrogen
PM	-	Press mud
PPM	-	Parts Per Million
SCSB	-	Southern Cooperative Series Bulletin

SI	-	Salt Index
SOP	-	Sulphate of potash
SUA	-	Sokoine University of Agriculture
TN	-	Total Nitrogen
TORITA	-	Tobacco Research Institute of Tanzania
TR	-	Total Respiration
TTB	-	Tanzania Tobacco Board
URT	-	United Republic of Tanzania
USA	-	United State of America
VPD	-	Vapour Pressure Deficit
WUE	-	Water Use Efficiency

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Tobacco (*Nicotiana tabacum*) is a dicotyledonous plant. It belongs to the Plantae Kingdom; Class; Magnoliopsida, Order; Solanales, Family; Solanaceae, and Genus; Nicotiana. According to Koprulu *et al.* (2009) the first genera of tobacco grew wild in warm climatic conditions of Southern hemisphere, before the exploratory expeditions carried out by Christopher Columbus and Amerigo Vespuci. Tobacco was in use among the inhabitants of America who chewed, smoked or sniffed it. Tobacco has come to the fore world wide after the discovery of America. Total world production of tobacco in 2008 was 6.7 million metric tonnes of which 2.8 million metric tonnes were produced in China, followed by Brazil (0.8), India (0.5) and the USA (0.36 million metric tonnes). While global area decreased from 5.3 million ha in the 90s to 3.8 million ha in 2008, productivity has improved steadily and reached 1 770 kg ha^{-1} in 2010 (FAOSTAT). Tobacco production in Tanzania started in Songea in 1930 and was introduced in Biharamulo in 1933 and then spread to other regions (Ishuza, 1984). Tabora contributed 56.6 % of the crop in 2003.

Tabora region is the leading flue cured tobacco producer in Tanzania. The quantity of tobacco produced in the country was 49 300 tonnes (URT, 2002-03). In the 2002-03 season, tobacco planted area was 57 438 ha, most of which (54 617 ha; approximately 95%) was planted in the long rain season. Average annual rainfall in Tabora region varies from 700 mm in the North – East to over 1000 mm in the West. The rainfall season starts in October and ends in May.

1.1.1 Soils

Mitchell *et al.* (1984) grouped the soils of Tabora region into seven groups based on the properties which directly affect their suitability for different kinds of land use. The groups are: 1) Rocky and very shallow soils, 2) *Isenga* soils, 3) *Kikungu* soils, 4) *Ibushi* soils, 5) Hardpan soils, 6) *Ipwisi* soils, and 7) Mbuga soils.

1.1.2 Suitable soils for tobacco

Among the seven soils mentioned, the most suitable and commonly used soils for tobacco production are; *Isenga*, *Kikungu* and *Mbuga* soils. *Isenga* soils are sandy soils, well drained whose texture is sandy loam or coarser within 100 cm of the surface. The soils cover 28% of the region. This soil type is suited to tobacco production in the high rainfall zone. The parent materials for these soils are colluvium, granite and old alluvium.

Kikungu soils are well drained and medium textured soils. The name implies red colour as it is. The sub soil texture is sandy clay loam, rarely sandy clay, while the top soil is loamy sand or loam, occasionally as heavy as sandy clay loam. The parent materials of these soils are metamorphic, basic igneous rocks and old alluvium. Their ability to retain nutrients makes them potentially more productive in years of good rains. They cover 17% of the Region.

Mbuga soils: includes all soils found in flat lowland areas where ground water table is within 100 cm of the surface and cover 17% of the Region. The soils are deep and of textures ranging from sand to clay, though sandy clay loam and clay predominate. The parent material is recent calcareous alluvium.

Tobacco production in Tabora region like many other tobacco growing regions share the same land with other crops such as maize, legumes and groundnut. Crop production is usually carried out in rotation. Tobacco stands as monocrop while other crops can be mixed. Tobacco uses high rates of NPK+B and CAN for top dressing in a season. In the next two or three seasons other crops are grown in the same fields and sometimes the fields are left as fallow.

1.1.3 Effect of long term use of NPK plus B formulations

Moore and Harris, (2004) reported that, many tobacco growers in USA waste money and nutrients each year by using higher nutrient rates of complete fertilizers than required rates. This is due to the fact that phosphorus does not leach very much, even on deep sandy soils. In addition, the amount of P taken up by the plant is very small in relation to the amounts typically applied. Therefore, large parts of the applied nutrients remain in the soil when the crop is removed. Tucker (1993) reported that available phosphorus (P) in North Carolina coastal plain tobacco soils increased to high levels (207 kg ha^{-1}) from continued application of high P fertilizer grades as 3-9-9, 4-8-12 and 6-12-18, even though lower P fertilizer grades were available. Plant food utilization data show flue-cured tobacco yielding 3 363 kg ha^{-1} removed only 11.31 kg of P_2O_5. The long-term application of P in excess of crop removal resulted in significant build up of P reserves in most tobacco soils. Fortunately educational effort had been enhanced through the cooperation of the fertilizer industry in making tobacco grades such as 6-6-18 and 8-0-24 available to growers. Since 1979, the rate of P applied for tobacco declined by 56 % (Appendix 1).

Camacho-Cristobal *et al.* (2006) confirmed that, boron in soil solution exists primarily as boric acid [B (OH) 3], which can be easily leached under high rainfall conditions leading to deficiencies in plants that grow there (e. g., many regions in Japan, China, USA, and

Brazil). On the contrary, under low rainfall conditions, B can not be sufficiently leached and therefore may accumulate to levels that become toxic to plant growth. This is very often in arid and semiarid regions with high-boron groundwater, where the accumulation of B in topsoil due to the evaporation of groundwater reaches toxic levels that reduce crop yields. B-rich soils also occur as a consequence of over-fertilization and/or irrigation with water containing high levels of B.

Since flue cured tobacco was introduced in Tanzania NPK was in use. In the1980s the only fertilizer mixture for flue cured tobacco in Tanzania was NPK 6:25:18 grade, with nutrient ratio 1:4:3 (Wahid, M. unpublished 1984). The application rate was 750 kg ha^{-1} supplying 45 kg N ha^{-1}, 187.5 kg P_2O_5 ha^{-1} , and 135 kg K_2O ha^{-1} reported that tobacco took about 20 – 35 kg P_2O_5 ha^{-1} implying that 167.5 – 152.5 kg P_2O_5 ha^{-1} was retained in the soils (Wahid, M. unpublished 1984). Osmond and Kang (2008), reported nutrients removal in North Carolina USA by flue cured tobacco leaves: N removal was 38.46 kg ha^{-1}, P_2O_5 was 6.79 kg ha^{-1} and K_2O was 70.14 kg ha^{-1} (Appendix 2). In 1990s up to 2009, NPK plus B (10:18:24 + 0.01) was in use, and in 2010 the NPK plus B grade was changed to 10:18:24 + 0.1. In this case, P and K in use were still high where by B is ten times more than the previous years (0.01%). Nitrogen is low because it does not stay in the sandy soils for long time, due to crop uptake, mineralization, leaching and volatilization (Kebede and Mikru , 2006).

Kelling (1999) of Wisconsin University reported soil boron interpretation summary (Appendix 3), in which soil B ranged from less than 0.2 ppm as very low, while above 2.5 ppm B is excessive to very high. Although boron application in tobacco growing areas of Tabora in 1960s to 1980s was 0.3 kg B ha^{-1} (Semoka, 1993), 1990s to 2000 was 0.05 kg B ha^{-1} while in the 2009-10 season the application rate was changed to 0.5 kg B ha^{-1} .

Boron accumulation over a long period could rise to high levels and become toxic to crops in fields.

Khan *et al.* (2002) studied the effect of intensive fertilization and cropping on micronutrient contents of soil solution and rice (*Oryza sativa*) samples. The soil type was a silt loam and had pH of 6.8, organic matter 2.16%, total nitrogen 0.06%, available phosphorus 9.0 mg kg^{-1}, and available potassium 0.20 cmol kg^{-1}. The treatments included control, N, NP, NPK, NS, NPK S Zn, NFYM and NPK FYM. Fertilizer doses used in the experiment were 60 kg N ha^{-1} from Urea, 20kg P ha^{-1} from TSP, 15kg K ha^{-1} from MP and 30kg S from gypsum. Samples were analyzed to see the concentration of Zn, Cu, Fe and Mn. According to Khan *et al.*, (2002), intensive fertilization and cropping for a period of 20 years brought changes in available Fe, Zn, Cu and Mn status of soil. Long term continuous fertilization with NPKS Zn decreased Fe, Zn, Mn and Cu contents in the soil because of the effect of S and Zn with NPK. In that case, NPK S Zn helped in increasing the biomass production hence withdrawal of higher amount of nutrients compared with other nutrients (Appendix 4). The sub-surface soil had low amount of nutrients compared with surface soil. In plots treated with NPK S Zn the following changes were noted; Zn decreased from 3.5 mg kg^{-1} in surface layer to 3.0 mg kg^{-1} in sub-surface layer, Cu decreased from 4.9 mg kg^{-1} in surface layer to 3.9 mg kg^{-1}in sub-surface layer, Fe decreased from 57 in surface layer to 43 in sub-surface layer and Mn decreased from 16.1 in surface layer to 7.7 in sub-surface layer. Uptake of all micronutrients was much higher when NPK was applied with S and Zn (Appendix 4). The decrease in Fe, Zn, Cu and Mn in 20 years occurred because of continuous uptake by plants without replenishment. The same way NPK+B has been in use in tobacco production for more than two decades without addition of other mined micronutrients.

The aim of this study therefore is to assess the residual effect of NPK+B formulation in order to seek ways to improve tobacco yield and quality in Tabora region.

1.2 Problem Statement

Flue cured tobacco production in Tanzania depends on NPK fertilizers use. The NPK fertilizers are supplied in ratios based on the nutrient requirements of the crop. Application rates are estimated from the crop uptake of the nutrients. Wahid (1984) the use of NPK 6:25:18 grade (nutrients ratio 1:4:3) in Tanzania. Application of NPK fertilizer was 750 kg ha^{-1} that is 45 kg N ha^{-1}, 80.6 kg P ha^{-1}, and 112.1 kg K ha^{-1}, According to Wahid (1984), tobacco took about 8.6 – 15 kg P ha^{-1} while the remaining 72 – 65.6 P ha^{-1} is retained in the soils.

In 1980s NPK fertilizer rate was 750 kg of NPK 6:20:18 ha^{-1}, 0.3 kg B ha^{-1} which provided 60 kg N ha^{-1},100 kg P ha^{-1} and 112.5 kg K ha^{-1} and 0.3 kg B ha^{-1} (Semoka, 1993). The recommended N of 80.5 kg ha^{-1} for flue cured tobacco in Tabora region is not enough.

Boron is a micronutrient which is incorporated in NPK fertilizers in Tanzania. Camacho-Cristobal *et al.* (2006) argued that with low rainfall conditions, B can not be sufficiently leached and therefore may accumulate to levels that become toxic to plant growth. Like wise Eguchi and Yamanda (1997) reported on the status of B in long term field experiment (26-29 successive crops) and concluded that only 10% of B applied to soil was absorbed by plants, 30-40% is left in the soil, while 40-60% was leached out from the top of the soil. They also observed that, the fixed form of B was the greatest portion of the B left in the soil followed by the adsorbed form. The hot water soluble form (considered as available to the plant roots) showed a tendency to slightly increase and may become toxic to others crops in the long run, Kline and George (1991) reported that residual boron (carried over

from one to the next) persists in some soils for up to 3 to 4 years. This is depended on the boron rate, soil type (texture), amount of irrigation, or rainfall like wise. Phosphorus and potassium have the tendency of remaining in the soil as residual nutrients and used by the next crop or build up in the soil. Build up of P, K and B could detrimental to other crops which rotate with tobacco.

1.3 Justification of the Study

There is a need to find out the levels of phosphorus, potassium and boron in the soil after a long time use of NPK + B fertilizers in tobacco growing areas of Tabora region in order to reverse the effect of excessive P and K in the soil and also to avoid boron toxicity to other crops which are rotated with tobacco. There is also the need to find out the optimum levels of fertilizer application in order to reduce tobacco production costs.

1.4 Objectives

1.4.1 General objective

To optimize NPK plus Boron (B) fertilizer application in order to increase yield and quality of tobacco in Tabora.

1.4.2 Specific objectives

(i) To evaluate residual levels of nitrogen, phosphorus, potassium and boron in selected tobacco growing areas of Tabora region.

(ii) To assess the adequacy of the residual nutrient levels for tobacco growth and yield

(iii) To determine the effects of the current NPK and B formulation on yield and quality of tobacco

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Plants Nutrients

Campbell (2000) reported that, essential elements of a plant include those that are required to complete the life cycle of a plant. Agronomists place most emphases on essential elements supplied by soil or feeding solutions. Macronutrients are nitrogen (N), phosphorus (P), potassium (K), Calcium (Ca), magnesium (Mg), and sulfur (S). Micronutrients are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo) and chlorine (Cl). These are required in relatively small quantities. Carbon (C), oxygen (O), and hydrogen (H) are supplied by the atmosphere and generally not considered limiting.

2.1.1 Plant critical value and sufficiency range for tobacco

A plant analysis interpretation is based on a comparison of nutrient concentration found in particular plant part taken at specific time with known desired value or ranges in concentration (Moore and Harris, 2004). One method of interpretation is based on "critical values". A critical value is the concentration below which deficiency is more likely to occur. This system defines only the lower limit of sufficiency range, providing guidance when the concentration found to exceed critical value. A more useful method of interpretation is based on sufficiency ranges, the optimum element concentration range below which deficiency occurs and above which toxicity or imbalances occur. This system of evaluation is currently in use in the soil, plant and water laboratory (AESL, 2004).

2.2.1 Nitrogen

According to AESL (2004), the critical level of N in many plants is around 3 %. In many plants N deficiency symptoms appear when the level is below 2.75 %. At this level crops yields and quality decline. The young plants are exceptional because the critical levels may be 4 % or more. In case of tobacco, N sufficiency range is 3.50 – 4.25 % (AESL, 2004). Therefore, it is important that the N level be maintained within prescribed limits of sufficiency range by proper use of N fertilizers.

2.2.2 Phosphorus

It has been reported by AESL (2004), that the P requirement of plants varies considerably and that tree crops have relatively low P requirements with the critical value ranging from 0.12 to 0.15 %. Tobacco P sufficiency range from 0.27 to 0.5 % (AESL, 2004). Soil test recommendations for P aim at avoiding deficiencies or excesses. The P content of plants is initially high and declines with age. P is mobile; it is high in young leaves and low in old leaves. Deficiency symptoms appear in old bottom leaves first.

2.2.3 Potassium

The potassium requirement of plants varies widely depending on plant species and the requirement is low in tree crops such as peaches and apples. The critical value of K in tree leaves ranges from 0.75 to 1.25 %. For grasses, the K requirement ranges from 1.20 to 2.00 %. The K sufficiency range for tobacco is 2.50 to 3.20 % and normally tobacco soils were heavily fertilized with K (AESL, 2004). According to these authors, soil test recommendation for K closely avoided deficiencies or excesses and heavy application of K, which can induce Mg deficiency. Potassium is mobile in plant and its deficiency symptoms appear in older plant tissues first and its concentration in the plant decreases with age. The K/(Ca + Mg) and K/N balances must be maintained at a proper level to

avoid deficiencies of Mg in the first instance and K in the second. High K can induce Mg deficiency in most plants and tree crops. Plants which are Mg deficient may have high K and Ca content as plant tends to maintain a constant cation concentration. Heavy application of K or N fertilizer can induce Mg or K deficiency respectively.

2.2.4 Magnesium

Magnesium is a fairly mobile element in plant. The deficiency symptoms occur in the older plant tissues and its concentration in plant tends to increase with age. The critical level for cotton is 0.30 % (AESL, 2004) .Vegetable crops such as tomato, turnips, and collards have high magnesium requirement with the critical level near 0.40 %. The sufficiency range of Mg for tobacco ranges from 0.20 to 0.65 %.

2.2.5 Calcium

The Ca requirement for plants varies widely, with grasses having the lowest requirement and legumes intermediate. Fruit crops and cotton have the highest requirements. Calcium sufficiency range for tobacco is 1.50 to 3.5 %. Since Ca is not a mobile element, deficiencies occur in the newer tissues. The critical values of Ca in plants also expressed in parts per million (ppm) ranges between 600 ppm to 1000 ppm for leaves (AESL, 2004).

2.2.6 Boron

Boron requirements vary considerably among crops. The optimum range in leaf tissue of most crops is from 20 to 100 mg kg^{-1} (AESL, 2004). The sufficiency range of boron in tobacco is from 20 – 50 mg kg^{-1}. Boron is not a very mobile element and deficiency symptoms occur in new emerging tissues (AESL, 2004).

2.2.7 Copper

According to AESL (2004), the normal range of Cu in many plants is fairly narrow, ranging from 5 to 20 mg kg^{-1}. When Cu concentration in plants is less than 3 mg kg^{-1} in the dry matter, deficiencies are likely to occur. The sufficiency range of Cu for tobacco is 5 – 60 mg kg^{-1}. There are some variations in the critical value for various plant species.

2.2.8 Zinc

The normal range of Zn in most plants is between 20 and 100 mg kg^{-1}. The sufficiency range of Zn in tobacco is 20 – 80 mg kg^{-1} and its toxicity is uncommon problem and does not generally occur until the Zn level exceeds 200 mg kg^{-1} (AESL, 2004). Zinc is not a very mobile element in plants and deficiency symptoms occur in newly emerging leaves.

2.3 Soil Test Critical Value

Lory and Scharf (2004) made recommendations on the critical values of soil nutrients after their research at University of Missouri. They stated that soil test critical value is the target soil test level for optimum crop growth. When soil test levels are below the critical value, crop yield and quality may be restricted by nutrient availability in the soil.

According to Lory and Scharf (2004) soil test recommendations for phosphorus (P) assigned a critical value of 18 to 20.4 kg ha^{-1}, depending on crop selection. Recommended potassium critical value was based on crop selection and soil cation exchange capacity (CEC). Studies indicated that soils in Missouri differ in the amount of P and K that was needed to raise soil test levels on a per unit soil test increase basis. Application of the equivalent of 110.8 kg P ha^{-1} raised soil test to 26.9 kg P ha^{-1} on a Putman soil from the claypan region compared with 58.2 kg P/ ha^{-1} for a Creldon soil from the Ozark region of Missouri., according to the authors average increase in soil test P for 4 Ozark soils was

approximately double that of 3 soils from the clay pan region. Similar differences have been observed among build-up requirements for potassium.

Differences among soils were related to region of the state, clay content and initial soil test level. Soils also differ in critical values. The same mineralogical and chemical properties that cause one soil to need double the P to raise soil test a specific number of units may also affect the soil test level needed to provide optimum growth potential.

2.4 Nitrogen form Availability and Uptake

According to Eckert (2010), soil nitrogen exists in three general forms; organic nitrogen compounds, ammonium (NH_4^+) ions, and nitrate (NO_3^-) ions. For the majority of plant, available nitrogen is in the inorganic N (also called mineral nitrogen) NH_4^+ and NO_3^- forms. Ammonium (NH_4^+) ions bind to the soil's negatively-charged cation exchange complex (CEC) and behave much like other cations in the soil. Nitrate (NO_3^-) ions do not bind to the soil solids because they carry negative charges, but exist dissolved in the soil water, or precipitated as soluble salts under dry conditions. Some NH_4^+ and NO_3^- may also exist in the crystal structure of certain soil minerals, and may be quite available. Nitrate moves freely toward plant roots as they absorb water.

Once inside the plant, NO_3^- is reduced to an ammonia form and is assimilated to produce more complex compounds. Because plants require very large quantities of nitrogen, an extensive root system is essential to allow unrestricted uptake. Plants with roots restricted by compaction may show signs of nitrogen deficiency even when adequate nitrogen is present in the soil (Eckert, 2010).

Kumaresan *et al.* (2008) conducted a field experiment from 2001 - 02 to 2003 - 04 at Vedasandur in India to study the effect of coconut (*Cocos nucifera* L.) coir pith compost at three levels which were 10.0, 12.5 and 15.0 t/ha in comparison with municipal compost at 25 t/ha, three levels of irrigation {0.5, 0.75 and 1.0 evapo-transpiration coefficient (ETc)} and three levels of nitrogen (50, 75 and 100 kg N/ha) on the yield and quality of chewing tobacco. From this experiment they found that, yields of first-grade leaf and total cured-leaf of chewing tobacco with municipal compost at 25 t/ha were comparable with that of composted coir pith at 10 t/ha. Irrigation at 1.0 ETc significantly increased the yields of first-grade leaf and total cured leaf by 19 and 17%, respectively compared with that at 0.5 ETc.

2.4.1 Effects of N in Tobacco

Flue-cured tobacco is very demanding in its N requirement. The regulation of the amount and timing of N availability is extremely important. Available N is needed to sustain full growth until flowering, because N deficiency in this period is likely to result in a yield reduction. After vegetative phase, N over fertilization leads to a reduction in cured-leaf quality (harsh tissue, darkening) and commercial value (Ikisan.com, 2009; Murthy *et al.* (2006). Marchetti *et al.*, (2006), conducted an experiment on nitrogen fertilizer with the aim: (i) to verify the influence of N rate on flue-cured tobacco yields and (ii) to estimate the contribution of the soil organic N stock to crop nutrition. This contribution was evaluated by means of an N balance applied to the soil–plant system and the effects of five N rates (0, 20, 40, 60, and 80 kg N ha^{-1}.) on flue-cured tobacco cv K326. Based on soil analysis, no P fertilizer was applied. Potassium was applied at the rate of 250 kg ha^{-1} (as potassium sulphate before the transplanting time). The mean yield of cured leaves was 4105 kg ha^{-1} in 1998, and 3740 kg ha^{-1}, in 1999.

According to Marchetti *et al.* (2006): Nitrogen Balance: Norg=Nfert−AGNmax−ΔNinorg. Where ΔNorg is the change in soil organic N storage, Nfert is the fertilizer N, AGNmax is the maximum plant aboveground N removal and ΔNinorg is the change in the soil inorganic N storage. In other words, the N rate of 80 kg ha $^{-1}$ increased cured-leaf yield by 4105 kg ha^{-1}, compared with the unfertilized control. This means that, in 1999, at the highest N rates, tobacco yield was stabilized on 3900 kg ha^{-1}. The maximum yield obtained in 1999 was lower than the mean yield obtained in 1998. Lower tobacco yields in 1999 were attributed to water-logging episodes that occurred in the weeks immediately following the tobacco transplant. The mean total N concentration in cured leaves was equal to 29.2 g N kg^{-1} in 1998 and to 22.1 g N kg^{-1} in 1999.

Plant above ground nitrogen removal changed the organic N storage estimated on the top 0.8 m soil layer in the time interval between tobacco transplanting and mid-September in 1998 and 1999. The amount of available inorganic N in soil at the transplanting time (Ninorg-initial) was on average equal to 8.66 g N m^{-2} in 1998 and 13.17 g N m^{-2} in 1999, and it largely exceeded the subsequent fertilizer N supply, especially in 1999. The amount of available soil inorganic N at the end of the balance period (Ninorg-end) was lower than that measured at the beginning.

The amount of organic N that can mineralize each year is reported to be commonly in the range of 0.5 to 3.5% of changes in soil organic nitrogen storage. Mineralization rates varying between 0.51 and 2.44 kg N ha^{-1} day^{-1}, depending on year and N rate. The estimated organic N decrease in the unfertilized plots represents the N amount that became available from the soil during the crop growth season, in addition to the initial inorganic N reserve. These amounts from the two sources have to be estimated at the beginning of a new season.

Xiao-Tang *et al.* (2008) conducted an experiment and confirmed that, nitrogen supply is the most important factor affecting yield and quality of flue-cured tobacco. A field experiment and an *in situ* incubation method were used to study the effects of soil N mineralization in the later stages of growth on yield and nicotine content of flue-cured tobacco in Fenggang, Jinsha and Guizhou Provinces in China. The yield and market value of flue-cured tobacco at Fenggang were much lower than those at Jinsha. However, the nicotine content of middle and upper leaves was much higher at Fenggang than at Jinsha when the same rate of fertilizer N was applied, which might be due to a higher N supply capacity at the Fenggang site. At later stages of growth (7–16 weeks after transplanting), the soil net N mineralization at Fenggang (56 kg N ha^{-1}) was almost double that at Jinsha (30 kg N ha^{-1}). While soil NH_4-N and NO_3-N was almost exhausted by the plants or leached and 5 weeks after transplanting, the N taken up at the later growth stages of growth at Fenggang was mainly derived from soil N mineralization, which contributed to high nicotine content in the upper leaves. Tie *et al.* (2010) reported that the amount of NH_4^+ - N extracted by a H_2O_2/KCl (hot extraction method) from the soil of cultivated land was about 50% the proportions of total N extracted in the form of NH_4^+ - N included both the fraction of NH_4^+ - N that is readily available for plants and fraction that is mineralizable on a long term basis. The two fractions may present the amount of the total N in the active pool of soil organic matter while the rest could be considered as linked to the fixed pool. According to Xiao-Tang *et al.* (2008), the order of soil N contribution to N buildup in different parts of leaves was: upper leaves > middle leaves > bottom leaves. Thus, soil N mineralization at late growth stages was an important factor affecting N accumulation and therefore the nicotine content in the upper leaves.

2.4.2 Phosphorus buildup in the Soils

Peedin, (2001) noted that phosphorus is not very leachable, even in sandy soils, and a good tobacco crop only removes about 7.42 kg P ha^{-1}. However, many times this amount has been applied annually or biennially to most tobacco fields over the years, resulting in at least "high" levels of available phosphorus in about 85 percent of the fields used for tobacco. Thom and Dollarhide (2002) reported about the residual fertility of Kentucky soils. He observed that, residual fertility has increased strongly during the past 25 years as a result of prolonged application of a nutrient from sources that exceeds nutrient removed in cropping. Large application of nutrients from P fertilizers, manure or lime resulted to the extra nutrients to become part of the residual forms, resulting to increased soil test values. According to Thom and Dollarhide (2002), P build up was recorded when an experiment to test P build involving five crops was carried up from 1975 to 1985. The crops were burley tobacco, maize, soybeans, alfalfa and grass-legume forage (Appendix 14). Each crop was established in five plots with five categories of soil P rating. Soil P rating was: very low(17 kg P ha^{-1}), low(17 – 34 kg P ha^{-1}), medium(34 - 67 kg P ha^{-1}), high(67 - 90 kg P ha^{-1}), very high (> 90 kg P ha^{-1}) .

Burley tobacco plots had the following initially soil P in 1975; very low (7.8 kg P ha^{-1}) to low (10.0 kg P ha^{-1}), medium (7.8 ha^{-1}) to high (13.4 kg P ha^{-1}), very high (72.9 kg P ha^{-1}). There was an increase in soil P in the 10^{th} year in all plots i.e. in 1985 in respective soil rating was: very low (2.2 kg P ha^{-1}), low (6.7 kg P ha^{-1}), and medium (9.0 kg P ha^{-1}) to high (13.4 kg P ha^{-1}) and very high (80.7 kg P ha^{-1}).

According to Thom and Dollarhide (2002), Maize (*Zea mays*) plots showed the following changes. Initially in 1975, soil P levels were; very low (19.0 kg P ha^{-1}) to low (37.0 kg P ha^{-1}), medium (7.8 kg P ha^{-1}) to high (23.5 kg P ha^{-1}), very high (25.8 kg P ha^{-1}). There

were changes in soil P in the 10th year in all plots in 1985. Soil P levels were very low (3.4 kg P ha^{-1}), low (22.4 kg P ha^{-1}), medium(14.6 kg P ha^{-1}) to high (37.0 kg P ha^{-1}) and changes very high tested P was 34.8 kg P ha^{-1}.

2.4.4 Residual effect of phosphatic fertilizers

Residual soil fertility is commonly defined as the amount of nutrient reported in the soil plus some variable amount expected to become available during the crop season from the nutrient's organic, exchangeable and slowly soluble forms. The residual forms are reservoirs which can replenish the plant available form during the growing season, as plant uptake removes nutrients from the soil solution (Thom and Dollarhide, 2002).

Rehman *et al.* (2006) carried out a research in a clay loam soil to observe the residual effect of phosphorus (P_2O_5) applied to wheat on sorghum fodder in a wheat-sorghum fodder rotation. The original soil analysis results at the beginning of the experiment showed, Olsen P 5.20 mg kg^{-1}, extractable K 145 mg kg^{-1} and organic matter 0.76% (Appendix 8). The phosphorus calculated for wheat ranged from 0 to 0.5 mgl^{-1} in 14 treatments.

After wheat harvest, Olsen-extractable P was determined in the soil from respective treatment plots which were treatments for sorghum plots. Sorghum was raised as fodder with seed rate of 75 kg ha^{-1}. The recommended dose for N was 62.5 kg ha^{-1}; no P fertilizer was added to the sorghum crop which was grown only on the carryover effect of P added to wheat. Plant samples (above ground portion of 20-25 plants) at booting stage were collected, oven dried, ground to pass through 0.5 mm sieve and analyzed for P concentration. Fodder was harvested after 55 days of growth and fresh fodder yield was

recorded. Plant samples collected were oven dried at 70° C to measure oven-dried weight of fodder phosphorus uptake and recovery were calculated the formula:-

$$\text{Recovery (\%)} = \frac{\text{P uptake from fertilized plot} - \text{P uptake from the control (NK) plot}}{\text{P added}} \times 100 \quad \ldots\ldots (1)$$

Olsen extractable P increased after wheat harvest. From Appendix (9) Olsen P increased with increase in fertilizer application. The increase ranged from 5.20 to 22.40. Maximum value 22.40 mg kg^{-1} was found in T14 which was developed by adding 69.00 mg P kg^{-1} soil. However there was a little bit reduction in native Olsen-P where no NK was applied and further decrease was observed in native Olsen –P when NK was applied. Sorghum raised on the residual P after wheat showed a progressive increase in fodder yield (Appendix 10). Maximum fresh fodder yield (32.28 t/ha) was obtained from T14 and minimum (15.17 t/ha) from control plots (with NPK) although the yield increased significantly due to residual effect of P but so when P fertilizer was applied directly. This means residual is not equal to and always less as direct application of P fertilizer. Further more data showed that oven dry fodder (11.59 t/ha) was significantly higher in T14 than other treatments. The maximum P concentration (0.12%) was found in T14 while minimum in T1 (0.06%). The maximum P uptake (13.91 kg/ha) was found in T14 while the minimum uptake (3.27 kg/ha) was found in control plots.

Phosphorus recovery was at maximum in T6 (15.06%) where 18.79 mg P kg^{-1} (86.06 kg P_2O_5 ha^{-1}) was added to the previous wheat crop. Phosphorus recovery correspondingly increased at lower rates of residual P (7.95mgP kg^{-1}) while at higher rates, P recovery was slightly decreased. According to Rehman *et al.* (2006), phosphorus uptake by the crop was fulfilled from residual P where it was applied each at 18.79 mg kg^{-1} to the previous wheat crop. Available phosphorus status of soils after sorghum harvest dropped (Appendix 10)

by almost half. The available P after sorghum fodder harvest was 10.95 mg kg^{-1} in T14 (residual P 22.40 mg kg^{-1} after wheat). Native Olsen P further dropped to 4.7 mg $kg^{-1}$where no NK was applied and to 4.60 mg kg^{-1} where NK was applied. According to Rehman *et al* (2006) imbalance application of fertilizers caused a great reduction in native P pool.

Ryan *et al.* (2008) conducted research on response to residual and currently applied phosphorus in dry land cereal/legume rotation in three Syria Mediterranean agro-ecosystems. They suggested that, given the complex nature of rain fed cropping systems in Mediterranean agriculture and the dynamic nature of P in soils, agronomic assessment of P fertilization must be long term in order to evaluate the residual effects. Thus, a 9-year study involved initial relatively large applications of P (0, 50, 100, 150, 200 kg P_2O_5 ha^{-1}) and yearly smaller dressings (0, 15, 30, 45, 60 kg P_2O_5 ha^{-1}) in a trial involving dry land cereals (wheat/barley) in rotation with legumes (chickpea, lentil, or vetch) at three locations with varying mean annual rainfall in Northern Syria. The mean annual rainfall in Breda was 270 mm., Tel Hadya had 342 mm and Jindiress had 470 mm.

Assessment was made on grain, straw and total biomass yield and crop P uptake and available P (Olsen). While crop responses varied due to seasonal rainfall fluctuations, they tended to decrease with increasing initial available soil P levels (2.7, 6.2, and 4.4 mg kg^{-1} for Breda, Tel Hadya and Jindiress, respectively). Residual P was not significant for cereals or legumes at any site, but direct P was significant for both crops at Breda and Jindiress, as well as for legumes at Tel Hadya. In contrast, residual and direct P significantly influenced Olsen-P, seasonal and total P uptake. With no P fertilizer, or where minimal amounts (15 kg P_2O_5 ha^{-1}) were applied annually, the balance between applied P and crop P uptake became increasingly negative.

Syers *et al.* (2008) studied about the concentration of Phosphorus in the soil solution and crop nutrients uptake. They observed that the concentration of phosphorus in the soil solution can range from 10^{-4}M (very high), to 10^{-6}M (deficient), to as low as 10^{-8}M, in some very low fertility tropical soils. They observed that concentrations can be related to the amount of P in the soil solution and crop uptake of P. Concentrations of 10^{-5}M correspond to 0.31mg P per litre in the soil solution. They had an assumption that the top 30 cm of soil holds 6cm of water (equivalent to 600 m^3 per hectare) and there was less than 0.2 kg P ha^{-1} in the soil solution to that depth. If a crop uses 37 cm of water during growth, there will only be about 1 kg P ha^{-1} dissolved in the soil solution, yet it may take up 20 – 30 kg P ha^{-1} during growing season. They argued that much larger uptake of P was possible because roots could absorb P from solutions with very small concentration and P was maintained in solution by desorption from the solid phase of the soil. There was strong evidence that P added to soils in fertilizers and manures was sorbed reversibly and that it was not irreversibly fixed in soil. They said the phenomenon applied even to very acidic soils in Brazil and Peru. Plant roots can take P accumulated in the soil as residues from applications of fertilizers and manures over a period of many years.

Most of the inorganic P added to soils in fertilizers and manures is usually absorbed initially, but it may become absorbed by diffuse penetration of phosphate ions into soil components (Spectrum Analytic Inc. 2010). Residual P contributes to the readily plant-available pool, but the rate of release may not be sufficient to maintain the critical value required to meet the P requirements. In such situations, P must be added in order to maintain the critical value to obtain optimum yields.

South Dakota State University provided data from a 12 years residual P study at their research farm. Maize and soybean were grown in rotation with no-till cultivation system.

In 1993, four soil P test levels, appropriate to South Dakota Standards were established by incorporating varying amounts of P containing fertilizer (10-34-0) into surface soil using a chisel plough. The levels described as low, medium, high and very high were 5, 8, 13 and 25 mg kg^{-1} Olsen P. At each of the levels of the soil P, 0, 10, 20 and 30 kg ha^{-1} of P were bend-placed manually for both maize and Soybean. Applying P by broadcast was compared with banding at the medium soil P level, using the same four amounts of P. Where P was broadcasted at 20 and 30 kg ha^{-1}, Olsen P increased to 17.6 and 32 mg kg^{-1}, respectively by year 2005 as a result of positive P balances with the treatments. Olsen P was maintained by the 10 kg ha^{-1} treatment but declined where no P was applied. To maintain the initial high and very high Olsen P levels required 20 and 30 kg P ha^{-1} applications, the latter was larger than P needed for optimal yield. The need for larger P inputs to maintain unnecessarily high levels of plant available P in the soil was similar to observation recorded in a study Tucker by (1993).

Soil with initial Olsen P values of 5 and 8 mg kg^{-1} showed a decline to 3.0 and 3.8 mgkg^{-1} while the two soils with 13 and 25mg kg^{-1} showed a decline to 5.3 and 7.7 mg kg^{-1}, respectively. In all cases the declines, when expressed in kg ha^{-1}, were less than the P removed in the harvested grain. This supported the view that less readily available P can be released to support P uptake by the crop as readily available P levels decline.

A greenhouse experiment was performed as a supplement to the field experiments in the logic that crop sequence is faster and that yield response to fertilizers is more likely to be found in such experiments than in the field (Giskin *et al.*, 1972). The aims of the experiment were to evaluate the build-up or depletion, during continuous cropping, of "available" phosphorus in soils with varying residual phosphate levels and to determine the contribution to yield of freshly applied and residual phosphates.

The pot experiment, with three soils and seven consecutive crops, received super-phosphate in amounts of 0, 19.4, 58.2, and 174.6 ppm P in 3 kg soil. After removal of the third crop, each of the four initial treatments was divided into four sub treatment groups. Rates of fertilization remained similar. Linearity of relationships was found between P-uptake and total amount of fertilizer applied, dry matter yield and P extracted by $NaHCO_3$ or water. For all three soils the freshly applied phosphate was more readily "available" than the residual phosphate but there was a decrease in dependence of yield response to freshly applied phosphate when the soil residual phosphate levels were high. In the Neve Yaar soil, the freshly added phosphate, expressed as ppm P in soil, produced roughly the same yield as an equivalent amount of $NaHCO_3$-extractable P whereas, in the Lachish soil, approximately two to three times more of fresh P has to be applied in order to approximate the same yield level of $NaHCO_3$-extractable P. This indicated a lower or slower fixation of phosphorus in the Neve Yaar soil and concurs with results found in the field experiments. Thus, some quantitative relationship between plant response to freshly applied and residual phosphate was found which was not capable of being calculated from data of the field experiments.

Gichangi *et al.* (2008) evaluated the external P requirement of two soils (Flagstaff and Qunu) from the Transkei region of South Africa with varying sorption properties using oat (*Avena Sativa* L) as a test crop. Eight levels of P application estimated from the langmuir equations that gave range of P concentrations in the soil solution. The rates were 0, 45, 90, 135, 180, 225, 270 and 315 mg P kg^{-1} for Flagstaff soil and 0, 10, 20, 30, 40, 50, 60 and 70 mg P kg^{-1} for Qunu soil and these resulted in equilibrium soil solution concentration of between 0 to 0.35 mg P l^{-1} for both soils. Biomass yield and tissue P concentration were increased significantly ($P \leq 0.05$) by addition of fertilizer P compared with control, the responses were curvilinear for both soils. Biomass yield, ranged from 1.35 to 3.35g $plant^{-1}$

for flagstaff soil and from 0.32 to 3.33g plant^{-1} for Qqunu soil. Trends of plant tissue P concentration were similar to those of biomass yield and were curvilinear for both soils with plant P concentration increasing with increased levels of P addition. The P concentration in the plant tissue was significantly increased by application of P fertilizer. The strong relationship between P in solution and biomass yield and P concentration in the plant indicate the usefulness of P sorption approach for making fertilizer P recommendations.

2.5 Phosphorus Fixation and Soil P Build Up

2.5.1 Phosphorus fixation

According to (Spectrum Analytic Inc. 2010), a soil with a weak P level and a medium-to-strong P fixation capacity will convert or "fix" much of the applied fertilizer P into unavailable forms and leave little for the crop. In many medium P soils, as much as 65% of the applied fertilizer P can be fixed. In extremely poor soils, as much as 90% of applied P may be fixed (Spectrum analytic Inc.2010). In these cases, applying only "crop removal" is inviting P deficiency. In such soils the P fixation capacity must be overcome by higher fertilizer P rates in order to have enough P left over for the crop. In other words, soils with less than optimum P levels must have some soil buildup P, to insure that there is enough for the immediate needs of the crop or other plants. Soil buildup application rates are typically discussed in terms of the ratio of applied P_2O_5 to soil test P buildup amounts. In order to increase the soil test P by 1 kgha^{-1}, 4.1 or 4.5kg of P_2O_5 in excess of crop needs should be applied. In ppm this would be 2 to 2.3 kg of P_2O_5 to raise the soil P 1 ppm. Agronomists normally refer to this as the buildup ratio. A buildup ratio of 4.1kg P_2O_5 to build up the soil test by 1.1 kg ha^{-1}soil test P would be simplified to 4. to 1.

Thom and Dollarhide (2002) (Appendix 13) illustrated how soil P buildup occurs. In their study, they looked at 17 different soils with initial soil test P levels ranging from 5.6 to 67.3 kg ha^{-1} using Mehlich 3 (M3) extraction. They applied 6 different rates of phosphorus ranging from 42.6 to 255.6 P2O5 kg ha^{-1}. Results clearly showed that the initial soil P test was a major factor in determining how much P_2O_5 is required to buildup the soil test P. When the soil P test is very low, the soil P buildup ratio is very high. However, as the initial soil P level increases, the buildup ratio gets lower.

2.6 Residual Potassium Build-Up in Soils

Murdock and Wells (2002) studied and observed that potassium fertilizer had been applied, sometimes in large amounts, to many Kentucky soils. Much of Kentucky's tobacco land had heavy applications of potassium fertilizer. On such soils where the level of available potassium has been increased to a high level, according to Murdock and Wells (2002) potassium applied as fertilizer is not used by crops in the year in which it is applied. Under ideal conditions, only 40 to 50 percent of the potassium applied is be recovered by the immediate crop Murdock and Wells (2002). The remainder is held in the soil and is slowly released to succeeding crops.

Murdock and Wells (2002) reported on how K changed in 10 years of continuous application to the same plots with the same crops. They carried out an experiment which had 5 plots which were categorized based on the soil K. The categories were; very low (VL<84 kg K ha^{-1}), low (L = 84 - 185 kg K ha^{-1}), medium (M = 185 - 280 kg K ha^{-1}) and high (H> 280 kg K ha^{-1}). Potassium build up was observed to be high in medium soil K category and was reduced in high soil K test category (Appendix 14). There was a decrease in residual K in very low and low soil K categories, because crop spent much more K and there was no excess K enough to build up. When potassium fertilizer was applied to soils

low in available potassium, some of the applied potassium reverted to the exchangeable form and some to the none changeable form. High rates of application increased the levels of potassium in the soil to a point which less and less K was reverted to the unchangeable form. At this point, lighter applications of potash fertilizers became sufficient to supply crop needs and maintained a high concentration of available K (Murdock and Wells, 2002).

Johnston *et al.* (1999) in South Africa studied the effects of the soil physical properties on soil K buildup in 51 different soils. They found that on average it required 1.4 K_2O kg to raise the soil 0.5 kg of K. However, the range of needed K_2O was from low of 1.72 kg to a high of 10.51 kg of the various soil physical factors evaluated, they found the most significant factors causing a higher buildup ratio were the overall soil CEC, the CEC of only the clay fraction of the soils.

2.6.1 Magnesium and potassium interaction in the field

Gurumurthy and Vageesh (2007) studied magnesium and potassium interaction in their field experiment which was conducted at zonal Agricultural Research Station, Navile Shimoga, Kharif to study the leaf yield and nutrient uptake by FCV tobacco as influenced by levels of K and Mg. The highest cured leaf yield was 1967 kg ha^{-1} (Appendix 16) significantly improved by application of 40 kg K_2O ha^{-1} from pressmud and 40 kg K_2O ha^{-1} from SOP at10 days after transplanting (DAP) also 15 kg MgO ha^{-1} was added. Due to synergistic effect of K and Mg (Appendix 16). The highest concentration of K was 3.35% in leaves from plots dressed with 40 kg K_2O ha^{-1} through pressmud and 40 kg K_2O ha^{-1} through sulphate of potash applied at 10 days after transplanting. Among different nutrients absorbed from the soil, potassium was removed in highest amount by the tobacco

crop (101.5 kg ha^{-1}) indicating the importance of K in the mineral nutrition of flue cured tobacco plant.

2.6.2 Boron in Soils and Plants

Herrera-Rodriguez *et al.* (2009) reported that, Boron is the most electronegative element in group III of periodic table, with the properties intermediate between metals and electronegative non-metals. Boron is broadly distributed in both lithosphere and hydrosphere. Boron concentration ranges from 5 to 10 mg kg^{-1} in rocks, 3 – 30 μ g kg^{-1} in rivers and about 4 – 5 mgl^{-1} in oceans. Boron is never found in its elemental form in nature, but is found in rocks and concentrated in deposits as borates, i.e. bound to oxygen together with sodium, calcium silicon or magnesium.

Most soils have less than 10 mg kg^{-1} boron and hence are considered to be poor in boron. Majority of boron is immobilized in rocks and not readily available for plants. Aluminium and ion oxides, magnesium hydroxide, calcium carbonate, organic matter, or clays can act as soil absorbing surfaces for boron .During rock weathering, boron goes easily into soil solution mainly as boric acid and is readily available for plant uptake, but this pool constitutes about 10% of total soil boron. In soils, boron movement follows the water flux; hence in cool humid climates soil boron is leached downward in soil profiles, whereas in soils of warm humid, or arid and semiarid regions, boron is likely to concentrate in surface horizon (Herrera-Rodriguez *et al.*, 2009).

2.6.2.1 Boron uptake by roots

In all soil solution boron is found mainly as soluble the soluble uncharged boric acid [$(B(OH)_3$]. Plants take up boron from soil in that chemical form. Boron is passively absorbed by root cell through simple diffusion mechanism, which can meet the plant

requirement of the element. Recent studies have demonstrated that channel proteins also perform boric acid transport into the root cells (Blevins and Lukaszewski, 1998).

2.6.2.2 Boron toxicity and plant development

According to Herrera-Rodriguez *et al.* (2009), boron toxicity has been recognized as an important problem limiting crop production in low rainfall and highly alkaline and saline soils in regions of Australia, West Asia and North Africa. In crop production, boron toxicity is more difficult to manage than its deficiency, which can be prevented by fertilization. However, fertilization with boron to avoid deficiency can result in toxicity since the concentration ranges between boron deficiency and toxicity is narrower than for any other plant essential nutrient.

2.6.2.3 Physiological effects of boron toxicity during the vegetative stage

Boron toxic concentration leads to different physiological effects during the life cycle of vascular plants. The effects include an inhibition in the percent germination of seeds for example maize (*Zea mays*), carrots (*Daucus carota* l.,) tomato (Lycopersium esculanta) Herrera-Rodriguez *et al.* (2009). The plant growth was reduced by boron toxicity, through inhibition of cell wall expansion and shoot and root growth. Reduces leaf chlorophyll contents and photosynthetic rates, lignin and suberin contents (Herrera-Rodriguez *et al.*, 2009).

In contrast to the deficiency symptoms, the initial symptoms of boron toxicity in plants occur in the older leaves tips and this portion becomes chlorotic or necrotic, progressing along the leaf margin and into the lamina. Toxicity effects appear to be loosely correlated with high concentration of boron in older leaves, especially in the margins. Boron may affect metabolic pathways by binding apoplastic protein to cis-hydroxyl group of cell wall membrane and by interfering with Mn dependent of enzymatic reactions.

Accumulation of high leaf concentration of B might lead to osmotic imbalances and might reduce the capacity of plant cells to resist photo oxidative damage. Excess B also results in increased membrane leakness, peroxidation of lipids and praline accumulation (Herrera-Rodriguez *et al.*, 2009).

2.7 Boron Build-up in the Soils

Eguchi and Yamanda (1997) reported on long term field experiment (26-29 successive crops) and concluded that only 10% of B applied to soil was absorbed by plants, 30-40% left in the soil, while 40-60% was leached out from the top of the soil. They also observed that, the fixed form of B was the greatest portion of the B left in the soil followed by the adsorbed form. The hot water soluble form (considered as available to the plant roots) showed a tendency to slightly increase with the time.

2.7.1 Effect of B on crop grain yield

Boron is one of micronutrients which are taken by plants in small quantities but influence crop yield, for example wheat grain yield increased with the increasing concentration of available B in soil as observed by Shafiq (2008). They recorded maximum wheat grain yield (3.10 Mg ha^{-1}) in response to residual B, with T6 where residual B concentration was 0.49 mg kg^{-1}. The minimum grain yield of 2.10 Mg ha^{-1} was found in the control treatment (Appendix 17). Rashid *et al.* (2006) reported that residual effect of B, applied to rice, on the successive cropping with wheat in which a dose of 1.0 kg B ha^{-1} was applied to the previous rice crop, resulted in 21% increase in wheat grain yield. Wheat grain yield increased as a result of the cumulative effect of 1.0 kg B ha^{-1} applied to both rice and wheat crops.

2.7.2 Boron effect on mineral nutrients of tobacco

Lopez-Lefebre *et al.* (2002) carried out an experiment to study the response of the nutritional state and biomass in tobacco plants administered different B treatments (B1: 5 mmol L^{-1} H_3BO_3, B2: 10 mmol L^{-1} H_3BO_3, B3: 20 mmol L^{-1} H_3BO_3). Tobacco plants were grown under controlled conditions and submitted to regular fertilization with macro- and micronutrients. The concentration of the elements organic nitrogen (N), phosphorus (P), potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chloride (Cl), and B were analyzed in roots and leaves. The increase in the B application in the culture medium translated as a progressive accumulation of this element and increased the biomass. The macronutrients N, P, K, and Na responded positively to the dosage of B, notably increasing in concentration.

According to Lopez-Lefebre *et al.* (2002) magnesium concentration responded negatively, declining considerably in the roots and leaves. The relationship between B and Ca in the experiment can be defined as synergetic. The root and foliar concentrations of Fe and Mn also increased with the B dosage, whereas Cu and Zn to a lesser degree diminished. Finally, the positive effect that increased B application exerted on biomass production in the tobacco plants could be explained by the general improvement in the nutritional state, particularly of the essential macronutrients N and P.

2.8 Zinc

Zinc in soils occurs in the following forms; i) Free ions (Zn^{2+} and $ZnOH^{+}$) and organically complexed zinc in solution, ii) adsorbed and exchangeable zinc held on surfaces of the colloidal fraction in the soil, comprising: clay particles, humic compounds and iron and aluminium hydrated oxides and iii) secondary minerals and insoluble complexes in the solid phase of the soil (Spectrum Analytic Inc. 2010).

According to Spectrum Analytic Inc. (2010), zinc has become important because it is involved in production of auxins, an essential growth hormone. It activates enzymes in protein synthesis, in addition it is involved in the regulation and consumption of sugars. It is necessary for starch formation and proper root development. Zinc influences the rate of seed and stalk maturation. It is necessary for the formation of chlorophyll and carbohydrates. The presence of adequate amounts in the tissue enables the plant to withstand lower air temperatures (Spectrum Analytic Inc., 2010).

High levels of soil P are commonly responsible for Zn deficiencies. Organic matter is a source of Zn, and the organic compounds in organic matter can chelate inorganic sources of Zn and increase their availability. High levels of arsenic in the soil, as often found in old orchard soils, can seriously inhibit both Phosphorus and Zinc uptake (Spectrum Analytic Inc., 2010). Low N availability decreases the vigour of plants to an extent that it may fail to take up adequate amounts of many other nutrients. Zinc uptake can be affected in this way. While Zn does not undergo the valence changes that Mn does in saturated soils, research has shown that rice cannot take up Zn as effectively under flooded conditions. The causes of this condition appear to be applicable to other crops in one degree or another. Plant roots appear to absorb Zn and Cu by the same mechanism. This causes interference in the uptake of one when the other is in excess in the root zone. It has been reported that additions of Mg can increase the uptake of Zinc (Spectrum Analytic Inc., 2010).

2.9 NPK Fertilizers

2.9.1 Long term use of NPK

Kebede, and Mikru (2006) studied the nutrient status of long term (over 15 years) fertilized soils of coffee plantation in south western Ethiopia. They studied the fate of the micro and macronutrients in the soil as a result of continued application of N, P and K fertilizer on

coffee plantation. The initial results from soil samples showed that average soil pH was 4.57. The total N of the soil ranged from 0.2 to 0.36% and average value was 0.25%. The available P content ranged from trace to 22 ppm and the average available P content was 5 ppm (Appendix 18), exchangeable K in soil was high although did not significantly differ compared with unfertilized sites. Nutrients commonly applied were N, P and K at 100, 50 and 100 kg /ha/years respectively (Devi *et al.*, 2007). Soil samples were collected and studied for the concentration of N, P, K, Fe, Mn, Cu and Zn. After 15 years of sample collection and analysis the results were as follows; the average soil pH was 4.57, the total N ranged from 0.20 to 0.36% and the average value was 0.25%. The organic C content was 2.96%. The available P content ranged from trace to 22 ppm and the average available P content was 5 ppm. According to Kebede and Mikru (2006) average available P content increased significantly in all fertilized plots compared with unfertilized sites. Unlike N, which was highly liable to mineralization, leaching and volatilization the residual effect and build up of P in the long term fertilized plot was highly observable. In general, the availability of P increased with the high dose of fertilizer in all treated plots.

The analysis of fertilized plots indicated that there were significant effects of the application on the concentration of available P in soil particularly P_2O_5 (66 $kgha^{-1}$) compared with control. Therefore, P fertilization was able to raise the P status of the soil. According to analysis K fertilization increased potassium concentration of the soil K_2O (134 kg ha^{-1}) and K_3 (201 kg ha^{-1}) compared with control. Soils were analyzed also for pH, CEC, Organic carbon and N, P and K (Appendix 18). As a result it was observed that soil pH in the fertilized soils showed a decreasing trend (acidity increased) and available Phosphorus in fertilized soils increased significantly owing to its low mobility. Potassium increased from 0.67mc/100g to 0.93 me /100 g at pH 6.0.

The results of laboratory analysis (Appendix 19) showed that the availability and concentration of micronutrients in all cases increased with decreased soil pH ranges in critical level. The Cu contents varied from 2.7 to 4.5 ppm and showed higher value in the soil. The iron and manganese contents of the soil were high and tended to be in the excessive range. The high Mn and Fe concentration in soil were certainly due to the low pH of the soil, which all were below pH 6. Therefore, by raising the soil pH the availability of Mn and Fe could be reduced and possibility of its toxic effects eliminated.

From Appendix 18, it was evident that application of fertilizer increased the availability of micronutrients such as Zn, Cu, Fe and Mn in all case compared with unfertilized plots. These results indicated that the solubility of these micronutrients was generally found to increase with the decrease soil pH. The Cu contents varied from 2.7 to 4.5 ppm and showed higher value in the soil. The Fe and Mn contents of the soil were high at pH above 6.0; they were 68.4 and 2 191ppm, respectively. The high Mn and Fe concentration in soil were certainly due to the low pH. The application of P- fertilizer was effective in every case, while K application had a positive effect only at higher application rates. In continuous application of P fertilizers, soil phosphorus showed significant changes both chemical form and its build up was highly observable.

2.9.2 Optimum levels of NPK fertilizers

Fan *et al.* (2006) reported that optimal N utilization by flue cured tobacco was achieved with 135 kg Nha^{-1} a minimum of 84 kg P ha^{-1} and 199.2 kg K ha^{-1}. The levels of N, P and K uptake in flue cured tobacco were 82.2, 11.6 and 105.1 kg ha^{-1}, respectively. In USA, Moore and Harris (2004) prepared a guide to help people to know how much of each nutrient is taken up by the tobacco plant throughout the season. Nutrients taken up and removed by a 3360 $kgha^{-1}$of tobacco were as follows: Nitrogen supply was 141 kg ha^{-1}

while nitrogen removed by tobacco was 94 kg ha^{-1}. Phosphorus supply was 29 kg ha^{-1} while phosphorus removed by tobacco was 17 kg ha^{-1}. Potassium supply was 288 kg ha^{-1}while potassium removed by tobacco was 175 kg ha^{-1}.

Martin-Ortiz *et al.* (2009) evaluated the efficiency of a NPK fertilizer (8:15:15) with a Zn lignosulfonate (ZnLS) adhered as Zn source for maize plants. The product was compared in three experimental designs with the same NPK fertilizer with $ZnSO_4$ adhered and with no Zn adhered. The first and the second assays were carried out in a growth chamber by using perlite and a calcareous soil as substrate and the third experiment was raised in two calcareous fields. In general, growth chamber experiments showed that plants treated with NPK + ZnLS presented the highest dry weight and Zn concentrations in shoots. Also the field experiments, the Zn concentration in shoots was significantly high in plants treated with NPK + ZnLS. The grain harvested showed that this treatment gave the highest values in one location, but in the other no significant differences were observed. Although further research was required, it can conclude that NPK + ZnLS product could be a suitable source of Zn for maize crops.

Makinde and Ayoola (2010) conducted an experiment on growth, yield and NPK uptake by maize with complimentary organic and inorganic fertilizers. Pre-planting soil and manure analysis showed that, total soil N was 0.2%, while N from organic manure was 1.8%. Soil available P was 1.7 ppm while P from organic manure was 0.5%. Exchangeable K, Ca, Na and Mg were 0.3, 3.7, 0.5, 0.5 $cmolkg^{-1}$, respectively. The Exchangeable K, Ca, Na and Mg were 0.12, 0.7, 0.7, 0.01 % respectively (Appendix 21). The growth and yield of maize cultivated with a complementary application of organic and inorganic fertilizer was assessed, compared with sole organic and sole inorganic fertilizers between in 2003 and 2004 at Ibadan, Nigeria in the degraded tropical rain forest zone. No fertilizer treatment was the control.

In the analysis of plant nutrient, the ear-leaf N content of sole inorganic fertilizer was highest (1.68%), followed by the control (1.12%), combined fertilizers (0.98%) and (0.84%) of sole organic fertilizer. The plant fertilized with sole organic fertilizer had the highest P content of (0.97%) while plants fertilized with inorganic fertilizer had (0.47%). A higher amount of phosphorus was supplied with sole organic fertilizer application relative to combination of organic and inorganic fertilizer application. P content of the leaves was higher than from a combined application of organic and inorganic fertilizers (Makinde and Ayoola, 2010).

The K content of manure was low. The K contents of sole organic fertilized crop were lower relative to combination of organic and inorganic fertilizers and also to the sole inorganic fertilizer application. Maize fertilized with sole inorganic fertilizer had the highest content of 1.91% K while those from a combination of organic and inorganic fertilizers were 1.70% K. Potassium content in leaves was high in sole organic fertilizer 1.53%. Control plots had a K content of 1.11%, which was an indication of a contribution from the soil K reserve. The initial exchangeable K was 0.3cmolkg^{-1} and 0.12% from soil K and organic K respectively, while after the plant uptake was 1.11% (Makinde and Ayoola, 2010).

Nutrient uptake; Total plant N uptake was highest with inorganic fertilizers which was 118 kg ha^{-1}, followed by the combination of organic and inorganic fertilizers, 68 kg ha^{-1}. Phosphorus uptake by the plant ranged from 16 kg ha^{-1} in the control to 39 kg ha^{-1} from the organic fertilizer plots. Plants from plots fertilized with inorganic fertilizer had uptake of 33 kg ha^{-1} (Makinde and Ayoola, 2010).

Potassium uptake was highest; 174 kg ha^{-1} from sole inorganic fertilizer followed by the combination of organic and inorganic fertilizers, 118 kg ha^{-1}. Potassium was not supplied to control yet it was high, that was possible because un exchangeable K from soil reserve became exchangeable and got into soil solution and was taken by the plant (Makinde and Ayoola, 2010).

2.9.3 The effect of combined nutrient on tobacco yield and quality

2.9.3.1 Effect of combined micronutrients, Fico Micron (composed of Zn, Fe, Mg and Cu) on the yield and quality of tobacco

Bakht, *et al.* (2006) conducted an experiment to study the effect of combined micronutrients, Fico Micron (composed of Zn, Fe, Mg and Cu) on the yield and quality of tobacco. The response of tobacco variety Rustica was studied under five micronutrients levels; 0, 5, 10, 15 and 20 kg ha^{-1}. It was noted that different levels of combined micronutrients had a significant ($P \leq 0.05$) effect on plant height, leaf area, green leaf yield, cured leaf yield, leaf grade index and leaf reducing sugar content. Maximum plant height was (51.00cm) and leaf area was 437.00 cm^2. Largest green leaf yield was 14 095.33 kg ha^{-1} while cured leaves yield 2 402.0 kg ha^{-1}leaf and grade index 18% was recorded in plots treated with 20 kg ha^{-1} Fico Micron. Various studies showed that optimum fertilizer application is very important for getting high yield and quality of tobacco. Khan *et al.* (2008) reported significant increase in leaf yield of the cured tobacco with increase in fertilizer application (N, P_2O_5 and MgO). Applied rates were; 0, 40, 45 kg ha^{-1} along with B at rates of 0, 5 and 10 kg ha^{-1} in silt loam soil with the following chemical characteristics; 7.7 pH, E.C. 0.40 (dsm^{-1}), 0.07 N% while the available P and k were 8.60 and 115 mg kg^{-1}, B (0.30 mg g^{-1}), Mg (6.8 mg kg^{-1}), Zn (1.10 mg kg^{-1}), Cu (1.65 mg kg^{-1}) and Fe (12.70 mg kg^{-1}). Maximum percentage of top quality leaves was obtained at a

higher dose of Cu fertilization. Deficiency of B resulted in extreme turgidity and breakage of the midribs of the leaves.

Khan *et al.* (2008) investigated the effect of some micronutrients on yield and quality of flue cured variety of tobacco in North West Frontier Province Pakistan. Fico-Micron (composition was 21.45% Zn, 25.69% Fe, 23.00% Mg and 29.5% Cu equivalent to 8.6, 10.3, 9.2 and 11.8 kg ha^{-1} for Zn, Fe, Mg and Cu respectively at the rate of 0.40 and 45kg ha^{-1} along with Boron (B) at rates 0.5 and 10kg ha^{-1} were applied. The study showed that different micronutrients rates significantly affected leaf area, green leaf yield and cured leaf yield, grade index. The maximum leaf area of 690.3 cm^2 was recorded (Appendix 6) when plants were treated with fico-micron and B at the level of 40:10 kg ha^{-1}. Maximum dry and green leaf yield were 21 060 kg ha^{-1} and 2 948 kg ha^{-1}, obtained by applying fico-micron and B at the rates of 45:10 kg ha^{-1} and 40:10 kg ha^{-1} respectively (appendix 5). The highest grade index was 71.0 % from plots treated with fico- micron and B at the rate of 40: 0 kg ha^{-1}. Maximum reducing sugar was (14.85 %) as recorded when plants were treated with 0:10 kg ha^{-1} Fico-micron and B. Maximum nicotine percentage was (2.25 %) obtained from 40:0 kg ha^{-1} Fico-micron. The best and superior rate of Fico-micron and B was 40:10kg ha^{-1}.

2.9.3.2 Effects of N, P, Zn, B and S on crop yields

Srinivasarao *et al.* (2008) evaluated Zn, B and S status of 1617 farmers' fields in 14 districts of the semi-arid tropical India. The soils of the sites were mostly Vertisols and Alfisols, and the soil texture varied from sandy loam to clay. In general, the soils were low in fertility, especially organic carbon (<0.5%) and available nitrogen (<280 kg ha^{-1}). The inputs of plant nutrient through external sources and organic matter additions were very low, and were the cause of low fertility and low organic carbon status. A number of on-

farm trials for crops response studies, were conducted in the districts of Madhya Pradesh and Karnataka during 2002-2006. In various trials, control was based on farmers' or farmers preference (FP) nutrient inputs mainly N and application of nutrient amendments , 50 kg zinc sulphate (10 kg Zn ha^{-1}), 5kg borax (0.5 kg B ha^{-1}) and 200 kg gypsum (30 kg S ha^{-1}) were included along with FP. These nutrients were broadcasted uniformly on the plot before the final land preparation.

Grain and stover or haulm weights were taken and brought to the ICRISAT centre at Patancheru (India). Response of crops due to Zn, B and S application along with N, P over Farmers' Practice (FP) in which only N and P only were applied. Finger millet (*Eleusine coracana*), maize (*Zea mays*), sunflower (*Helianthus annuus*), soybean (*Glycine max*) and groundnut (*Arachis hypogaea*) showed that significant yield increase in all the crops due to balanced nutrition treatment which includes Zn, B and S along with N and P compared with FP in which N and P only were applied (Srinivasarao *et al.*, 2008).

Treatment Zn, B, S + FP, yielded 44% more stover, 56% grain yield and 48% total biomass over farmers' practice in case of finger millet. In maize, Zn, B, S + FP treatment yielded 28% and 52% higher stover and grain yield than FP. Sunflower yielded 72% more stover and 156% grain with Zn, B, S + FP treatment than FP (N+P). Significant stover (71%) and grain (70%) in soybean was obtained with Zn, B, S + FP treatment. In case of groundnut, significant yield response was obtained in stover (45%), grain (55%) and total biomass (47%). In three micro watersheds in Guna district in Madhya Pradesh (Kailashpur, Baradokala and Banjari Barri) application of B and S together significantly improved the grain and haulm yields of soybean (*Glycine max*) over control. (Srinivasarao *et al.*, 2008).

Grain yield increased from 740 kg ha^{-1} (FP) to 1340 kg ha^{-1} (B+S+FP) over FP. Haulm yield increased from 980 kg ha^{-1} (FP) to 1 700 kg ha^{-1} (BS + FP). There was significant residual effect of B+S applied to soybean to following chickpea (*Cicer arietinum*). Grain yield of chickpea increased from 1 050 kg ha^{-1} (FP) to 1550 kg ha^{-1} (with B+S+FP). While haulm yield increased from 1 510 kg $ha^{-1}$to 1 790 kg ha^{-1} with B+S+FP treatment. The yield increase was 48% in grain and 18% in haulm with B+S+FP over FP.

According to Srinivasarao *et al.* (2008), uptake of Zn, B and S by different rainfed crops in farmers' fields in five districts of Karnataka indicated the significant increase in uptake of Zn, B an S with balanced nutrition over farmers' practice of only NP application. However the extent of increase varied among nutrients as well as crops. Zn, B and S uptakes increased by 66%, 22% and 59% in finger millet, 76%, 11% and 38% in maize, 165%, 93% and 68% in sunflower, 113%, 60% and 125% in soybean and 125%, 64% and 55% in groundnut. The extensive Zn, B and S deficiencies was due to poor organic carbon status of soils (Srinivasarao et al., 2006) and depletion under continuous cropping without application of these plant nutrients. Low levels of organic carbon in these soils were primarily due to high temperature and low rainfall in these regions and also due to low or little organic matter additions.

Coarse textured, calcareous, alkaline or sodic soils having high pH and low organic matters were generally low in available Zn. Results demonstrated significant yield responses of different rainfed crops due to application of Zn, B and S + N+P over farmers' practice (Srinivasarao *et al.*, 2008). The responses of crops to the application of Zn, B and S varied across crops. The crop yields and nutrient uptake responses were clearly significant and of similar magnitude to those reported for field crops under irrigated agriculture.

According to Srinivasarao *et al.* (2008), the best results were achieved when the application of Zn, B and S combined with the application of N+P. Besides direct effect of these nutrients, there was considerable residual effect on succeeding crops. Under B and S deficient conditions in soil, there was about 50% grain yield of post-rainy chickpea on Vertisols of Central India due to B applied to rainy season. Results emphasize the need for better management strategies to utilize residual effects more efficiently under farmers' conditions. In all the crops, significant increase in uptake of Zn, B and S were obtained in different rain fed crops. Increase in Zn uptake was more than 100% in sunflower, soybean and groundnut.

2.9.4 Effect of long term fertilization and cropping on micronutrient cations of soils

Khan *et al* (2002) studied the effect of intensive fertilization and cropping on micronutrient contents of soil solution and rice (*Oryza sativa*) samples. The initial soil was silt loan in texture, pH 6.8 organic matter was 2.16%, total nitrogen was 0.06%, available phosphorus was 9.0 mg kg^{-1} and available potassium was 0.20 cmol kg^{-1}. The treatments include control, N, NP, NPK, NS, NPK S Zn, NFYM and NPK FYM. Fertilizer doses used in the experiment were 60 kg N ha^{-1} from Urea, 20 kg P ha^{-1} from TSP, 15 kg K ha^{-1} from MP and 30kg S from gypsum. The treatments selected for the study were: control, N, NP, NS, and NPKS Zn. The samples were analyzes to see the concentration of Zn, Zn and Mn. Application of N showed an increase only in available Fe and Mn over control. The long term application of P (TSP) increased available total and soil solution concentration of Zn, Cu, Fe and Mn to be taken up by rice crop.

Intensive fertilization and cropping for a period of 20 years brought change in available Fe, Zn, Cu and Mn status of soil. The treatments; control, N and NS were identical and did not show any effect on these nutrients. However, the addition of P significally increased their

concentration in soils of respective plots among P containing treatments, the effects of NPK S Zn was significantly higher than NP and NPK because of Zn content. The concentration of all micronutrient cations in subsurface soil decreased over surface soil in NP, NPK and NPK S Zn treatments while in control N and NS treatment tended to increase over the control (Khan *et al*., 2002).

The Cu content of soil from P containing plots was remarkably higher than remaining three treatments. The contents were lower by 50% in subsoil. The Fe and Mn ranged from 39 to 45 mg kg^{-1} and 8.3 to 9.3 mg kg^{-1} soil respectively, irrespective of depth. The higher status of Zn in the NPK S Zn treated plot was possibly due to long continued application. Lower Fe, Mn and Cu were possibly the effect of S and Zn fertilization. Application of S and Zn with NPK helped in increasing the biomass production and hence withdrawal of higher amount of nutrient compared with other nutrients (Khan *et al.*, 2002).

According to Khan *et al.* (2002) uptake of micronutrient was higher in case of NPKS Zn treatment and it was very much higher than all other treatments. Uptake of all micronutrient cations were very high when all common fertilizer NPK and additionally S and Zn were applied. This indicated that the balanced fertilization can greatly influence uptake of micronutrient cations in presence of S and Zn.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Areas

The study was carried out in four districts in Tabora region namely Urambo, Uyui, Tabora and Sikonge districts which are major tobacco growing areas in the region. In each district, five soil samples from five farms were collected to make a total of twenty samples for analysis. The criteria for selecting the site were; 1) a farm which was under tobacco farming for more than four years, 2) farms in which NPK fertilizers were used. In order to assess the residual levels of NPK and B, composite soil samples were taken from tobacco farms that had been under tobacco production for more than 4 years.

3.1.1 Soil Sampling

Soil sampling was based on three soil types:

a) Isenga soils (Lowlands sandy soils)

b) Kikungu soils (Alfisols)

c) Mbuga soils (Vertisols)

The research started with soil sampling from four districts which are Urambo, Uyui, Sikonge and Tabora municipal. In each district five farms were sampled. The history of fertilizer use and crop rotation in each farm sampled is summarised in Appendix 22. Five soil samples were taken from each district, two samples from Kikungu soil, and two samples from Isenga (sandy) soil and one sample from Mbuga (Vertisol) soil. In total there were 20 soil samples.

3.1.2 Collection of soil samples

Composite soil samples were collected from four districts; Urambo, Uyui, Sikonge and Tabora municipal. Each District was represented by one village where tobacco was under

cultivation for more than four years. The selected villages were; Yelayela in Urambo District, Ugowola in Uyui District, Ntalikwa in Tabora Municipal and Mitowo in Sikonge District. Composite soil samples representing each farm were taken at 0 – 20 cm depth from an area of one hectare. Quartering was done to get one kg of soil sample from each farm. In total 200 soil samples were collected from the study area; 20 samples for chemical analysis and 180 samples for pot experiment from 20 different farms in four districts; Urambo, Uyui, Sikonge and Tabora Municipal.

3.2 Soil Analyses

Twenty soil samples were taken to Sokoine University Agriculture (SUA) for nutrients contents determination. The analyses involved total nitrogen (TN), extractable P, K, Ca, Mg, Zn, Cu, Mn, Fe, cation exchange capacity (CEC) and soil pH. Soil TN was determined using the semi-micro Kjeldahl digestion followed by distillation.

Phosphorus was extracted by the Bray I method (Bray and Kurtz, 1945) and determined by spectrophotometry at 884nm – 890nm wavelength. Potassium, Ca and Mg were extracted by 1M CH_3COONH_4 at pH 7.0 (Rhodes, 1982). The cations were determined with the atomic absorption spectrophotometry. Iron, zinc and manganese, were obtained by the DTPA method and determined by the atomic absorption spectrophotometry. Boron was not extracted due to lack of chemicals.

3.3 Experiments Carried Out

There were two experiments. A pot and field experiment. The pot experiment was carried out at Tumbi located in Tabora Municipality. The field experiment was carried out at Ntalikwa village 7 km South-East of Tumbi in Tabora Municipality.

3.4 Pot Experiment

The experiment was conducted in pots, each contained 10 kg of soil. The experiment had six treatments replicated three times making a total of 18 pots for each district for each of the soil types that is Kikungu and Isenga. In addition, 18 pots of Mbuga soils from Urambo and 18 pots of mbuga soils from Tabora districts were included in the experiment. The total number of pots was 180 for the ten soil samples collected from the 4 districts. In each pot one seedling was transplanted making a total of 180 plants in the whole experiment.

Treatments used in the experiment were; (i) Control (T1) in which no fresh fertilizer was applied. In this treatment tobacco growth and development depended on the residual nutrients of respective farms. (ii) Recommended nitrogen only (T2), in which urea was used to make 40.5 mg N kg^{-1} to test the ability of the tobacco plant to use P, K, B and other nutrients from soil reserve (residual nutrients). (iii) Recommended rate (T3) in which 30g of NPK +B (10:20:18 +0.1), equivalent to N, P, K, and B levels of 300.0, 238.0, 598.0 and 3.0 mg kg^{-1} respectively in order to compare them with other rates in tobacco production performance. Treatment four (T4) was 45g of NPK +B (10:20:18 +0.1), equivalent to N, P, K, and B levels of 450.0, 356.4, 896.4 and 4.5 respectively. This rate is higher than recommended. (v) Treatment five (T5) was 45g of NPK +B (10:20:18 +0.1), equivalent to N, P, K, and B levels 450.0, 356.4, 896.4 and 4.5 respectively. Magnesium 50 and zinc 10 mg kg^{-1} were added to test performance of tobacco plant when these nutrients were added to NPK +B fertilizer rates. (vi) Treatment six (T6) was 45g of NPK +B (10:20:18 +0.1) and 5g CAN, equivalent to N, P, K, + B , Mg and Zn levels 585.0, 356.4, 896.4, 4.5, 50 and 10 mg kg^{-1} respectively. In this treatment was included to test a higher rate of N and the usefulness of CAN in the tobacco fertilization.

Table 1: Levels of different nutrients tested in the pot experiments

Treatment (T)	Amount of nutrients (mg/kg) applied					
	N	P	K	B	Mg	Zn
T1	*	*	*	*	*	*
T2	40.5	*	*	*	*	*
T3	300.0	238.0	598.0	3.0	*	*
T4	450.0	356.4	896.4	4.5	*	*
T5	450.0	356.4	896.4	4.5	50.0	10.0
T6	585.0	356.4	896.4	4.5	50.0	10.0

* A nutrient not applied

3.4.1 Mixing Magnesium and Zinc with soils

Mixing of Mg and Zn in soils for treatments five and six was done on 20 January 2010. These chemical nutrients were in very small quantities hence direct application could be very much localized and plant roots could not reach the nutrients easily. Thoroughly mixing of these chemical nutrients with soil before sowing was the only proper way. The soil was ground to pass through a 2mm sieve. Each pot was filled with 10 kg of the respective soils mixed with Mg and Zn. The amount of magnesium was in 15.213g MgSO4.7H2O equivalent to 50 mg Mg kg^{-1} soil. The amount of zinc was in 3.74g of ZnO equivalent to 10 mg Zn kg^{-1}soil. For each soil types 30 kg of soil represented a treatment in 3 replications. Magnesium and zinc were finally mixed thoroughly with the prepared soils.

3.5 Management of Tobacco Plants in the Pot Experiment

3.5.1 Transplanting of tobacco seedlings

Eight weeks old tobacco seedlings were transplanted on 24 January 2010. The activity was done two days after water equilibration. The variety used was K 326.

3.5.2 Water management in pots

The water field capacity of each soil was determined and water equilibration was done one day before transplanting tobacco seedling in pots.

3.5.3Procedure for field capacity determination

The soil sample was sieved through a 2mm wire mesh. The soil was filled three times in a 100 cm measuring cylinder. Average weight of each soil type was determined. The soil in the measuring cylinder was wetted by 15 ml of water. The water front was recorded and the volume of wetted soil recorded as well. Then the volume of water to wet 100 cm soil in the cylinder was calculated. The calculated soil in the cylinder and corresponding amount of water was equated with 10 000 g (10 kg) soils of pots to get the amount of water required to wet soil in the pots. The amount of water obtained was respective field capacity (FC) of the soil. The amount of water applied to respective soil in pots was 90% of the calculated FC to allow air to occupy space in the soil (Appendix 27). Water was applied in pots to field capacity after every 2 days.

3.5.3 Fertilizer application

Basal fertilizer application was done on 1 February 2010 and top dressed on 15 February 2010. For treatment 2, the amount of urea to be applied was 0.88 mg per pot in split application. For the basal application, 0.44g of urea per pot was applied and the same amount used for top dressing. For treatment 3, 30 g of NPK +B (10:20:18 +0.1) was to be applied. For basal application 20 g was applied and the remaining 10 g was top dressed. For treatment 4, 45 g of NPK +B (10:20:18 +0.1) was applied. For the basal application 30 g was applied and the remaining 15 g top dressed. For Treatment 5; 45g of NPK +B (10:20:18 +0.1) was applied; of this, 30 g was used for basal application and the remaining. 15 g was top dressed while Mg and Zn were already applied before transplanting. Treatment 6; 45 g of NPK +B (10:20:18 +0.1) and 5 g CAN were applied. In basal application, 30 g of NPK +B (10:20:18 +0.1) was applied and top dressed with the remaining 15 g of NPK +B (10:20:18 +0.1) and 5 g CAN. Magnesium and zinc were already applied before transplanting.

3.6 Field Experiment at Ntalikwa village

The aim of this experiment was to determine the effects of the current NPK and B formulation on yield and quality of flue cured tobacco in farmer's fields.

3.6.1 Description of study area

The experiment was conducted at Ntalikwa village located 6 km South West of Tabora town centre. The field used was among sites which were sampled for soil fertility assessment. The soil chemical characteristics results are given in Table 3. The plot used was under continuous tobacco cultivation alternating with maize since 1990s until year 2007, when the plot was left uncultivated. The owner of the field stopped growing crops on the field because of poor yields.

3.6.2 Land preparation and tobacco transplanting

Land preparation was done at the end of December, 2009. Transplanting of tobacco seedling was done on 1st January, 2010. Tobacco seedlings for the experiment were obtained from the Tobacco Research Institute of Tanzania (TORITA) nursery. The variety used was variety K 326. Seedlings were transplanted on ridges spaced one metre apart while plant spacing within a row was 0.6 m. The experiment had three replications each having six plots of 5 m x 6 m size. The treatments were completely randomized. The treatments tested were derived from Appendix 24 are summarized in Table 2 below.

Table 2: Levels of different nutrients tested in the field experiment

Treatments(T)	Amount of nutrients applied (kg/ha)						
	N	P	K	B	Mg	Zn	Cu
T1	*	*	*	*	*	*	*
T2	80.5	10	53.12	*	*	5	2.5
T3	72.5	39.6	99.6	0.5	*	*	*
T4	72.5	39.6	99.6	0.5	50	5	*
T5	75	59.4	149.4	0.75	100	20	*
T6	100	79.2	199.2	1	100	20	*

*A nutrient not applied

3.6.3 Management of tobacco plants in the pot experiment

3.6.3.1 Fertilizer application

The fertilizers were applied by split application that is, basal application which was done on 16 January, 2010 and top dressed two weeks after basal application. Basal application involved 50% of the total amount to be applied and the remaining 50% of the fertilizers was used for topdressing.

3.6.3.2 Weeding, pest and suckers control

Weeding was done to eliminate weeds which would have utilized nutrients in competition with tobacco plants. Cultivation to loosen the soil and allow air circulation in the root zone for roots respiration was done on 29 January, 2010 and 14 February, 2010. Re-ridging followed to keep ridges in required form. Insect pests such as grasshoppers, aphids and Lepidoptera caterpillars were controlled by Selecron (15ml l^{-1} of water) insecticide which was applied on 15 January 2010. Plants took 56 days to flower. Topping was done when 50% of flower buds appeared. Suckers emergence was prevented by Yamaotea super (10 ml l^{-1} of water) immediately after topping of tobacco plants 63 days after transplanting. The average number of leaves per plant was 18.

3.7 Data Collection for both Pot and Field Experiment

3.7.1 Leaf length

The average leaf length of plants of each treatment was measured and recorded. The measurement of the leaves was done at maturity before picking. Bottom leaves were the first to be measured because they were the first to mature followed by middle leaves and finally the top leaves.

3.7.2 Harvesting and curing

Harvesting started 50 days after transplanting tobacco in the field. Harvesting was done by picking the lowest positioned and mature leaves. Picking was guided by signs of maturity which appeared on leaf margins and lamina. Leaf margins and lamina changed from dark green to light green and light yellow colour. Harvested leaves were weighed to get fresh / green weight.

Curing was done immediately after harvesting. After curing leaves were conditioned by allowing them to absorb moisture from the atmosphere to become some how elastic for easy handling. Cured leaves were weighed to get dry weight per hectare and then they were graded according to leaf size, colour and leaf position when it was on tobacco stalk. The tobacco classifier classified the graded tobacco according to the national grades (Appendix 28).

Grade index is the ratio of the value of tobacco in the market over the dry barn weight, that is, the weight of tobacco after curing process before grading. Graded tobacco had some leaves which were rejected and could not be sold, therefore tobacco of good quality have high grade index. Low quality tobacco fetches low price which also gives low grade index (GI).

$$\text{Grade index (GI)} = \frac{\text{Grade value X graded tobacco Weight}}{\text{Barn dry weight of leaves}}$$

3.7.3 Determination of nutrient content of tobacco leaves

Nutrients assessed were: nitrogen, phosphorus, potassium, calcium, magnesium, copper, and zinc. Nitrogen content determination was done by micro-Kjeldahl method. Calcium, K, Mg, P, Cu, and Zn were extracted by dry ashing and followed by distillation of the ash.

Ca, Mg determined by atomic absorption spectrophotometry. Phosphorus was extracted by ascorbic acid method, determined by atomic absorption spectrophotometry. Nutrients comparison was done by standard nutrients indices (Campbell, 2009). Boron was not determined due to lack of chemicals.

3.8 Data Organization and Analysis

Recorded data for leaf size, green leaf weight and dry leaf weight and plant nutrients concentration were organized in Excel programme and analyzed by Costat computer programme.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter gives results and discussion for both pot and field experiments. Results and discussion presented include soil characteristics of sampled areas, development of plants in the experiments, the effect of NPK, B, Mg and Zn on leaf length, leaf weight, leaf nutrient concentrations and grade index. Comparison between pot and field experiment are also discussed in this chapter.

4.1 Soil Characteristics of the Study Areas

Soil characteristics were determined in order to evaluate residual level of nutrients in selected tobacco growing areas. Table 3 shows the results of different proportions in soil samples collected from the study areas which were taken to SUA laboratory for analysis. The Table contains districts and respective farmers whose fields were sampled, chemical properties including total nitrogen, available P, exchangeable cations: K, Ca, Mg and CEC (me/100 g) and micronutrients such as Zn, Cu, Mn and Fe. Table 4 shows results in which nutrients and CEC appear in ranges, the mean value and the status.

The results were interpreted based on the critical values established by National Soil Service given in Appendix 7. Total nitrogen in all sites was low to very low ranging from 0.03 to 0.18 % (Table 4). Available phosphorus level was medium to high ranging from 5.62 to 60.83 mg/kg soil. Exchangeable potassium was low to medium ranging from 0.06 to 0.81me/100 g. Exchangeable calcium was very low to high, ranging from 0.01 to 4.4 me/100 g but most soils marked very low to very high in calcium. Magnesium levels ranged from very low to medium i.e. from 0.04 to 1.8 me/100g soil (Table 4). Cation exchange capacity (CEC) of the soils was low to medium i.e. 6.4 to 23.33 me /100 g soil.

Table 5 shows the chemical soil characteristics results of soils used in the pot experiment. The same Table shows districts, farmers' names, villages in which farms are located and the measured parameters.

In average soil sample taken had low nutrients levels. Nitrogen level was relatively high in Urambo soils (0.08%), followed by Tabora (0.06%). Sikonge had higher level of P (34.72 mg kg^{-1}), followed by Tabora (31.44 mg kg^{-1}). Sikonge had highest levels of K (0.18 me /100 g), Soils in Urambo had higher Mg (0.68mg kg^{-1}), followed by Sikonge and Uyui (0.61mg kg^{-1}). Zinc was relatively higher in Uyui (0.24 mg kg^{-1}). The cation exchange capacity (CEC) was high in Urambo (14.30) soils followed by Sikonge (9.16).

Zinc levels were low ranging from 0.01 to 0.7mg kg^{-1} soil. Copper content was also low ranging from 0.12 to 0.97mg kg^{-1} soil. The levels of manganese were low too, with amounts ranging from 12.2 to 87.35 mg kg^{-1}. On the other hand, iron levels in the soil were normal ranging from 8.42 to 78.5 mg kg^{-1} soil.

Considering the results in terms of macronutrients and micronutrients it can be concluded that the soils were low in N, while levels of P and K were high showing that long term application in tobacco farm have considerable accumulation in the soils (Table 3). In the case of micronutrients, the levels were low and the soils were deficient except for Fe. The results imply that fertilizers supplied NPK+B only while other essential micronutrients are mined and not returned into the soils.

Table 3: Soil chemical characteristics of farms in Uyui. Tabora, Sikonge and Urambo districts

District	Farmer No.	Farmer	Total N (%)	Bray 1-P(mg/kg)	K	Ca	Mg	Zn	Cu	Mn	Fe	CEC
					mc/100g			mg' kg				
Uyui	1	James	0.03	24.75	0.06	0.5	0.33	0.05	0.15	27	28.28	6.4
	2	Kashindye	0.08	28.53	0.35	3.18	1.21	0 53	0.97	36.7	55.70	13.2
	3	Hussein	0.05	19.88	0.11	0.76	0.44	0 20	0.37	46.8	31.8	8.8
	4	Noah George	0.04	9.48	0.19	0.78	0.63	0.35	0.2o	55.57	25.42	9.2
	5	Shekipindi	0.04	21.48	0.07	0.97	0.46	0.06	0.26	54.7	15.49	7.6
		Average	0.05	20.82	0.16	1.24	0.61	0.24	0.40	44.15	31.34	9.04
Tabora	1	Kavelele	0.06	26.78	0.20	0.01	0.51	0.06	0.19	50.6	35.00	8.8
	2	Mwinyi	0.05	20.81	0.15	1.03	0.40	0.01	0.40	63.9	9.59	8.2
	3	Mduma	0.06	32.81	0.08	0.71	0.46	0.01	0.33	30.5	42.4	8.8
	4	Kisengi	0.05	46.65	0.10	0.48	0.36	0.06	0.15	61.8	15.3	8
	5	Mohamed	0.07	40.78	0.28	2.29	0.65	0.70	0.51	36.8	28.00	9.8
		Average	0.06	31.44	o.16	0.96	0.050	0.18	0.33	47.96	26.94	8.71
Sikonge	1	Magope	0.05	25.25	0.08	0.82	0.41	0.11	0.29	40.5	78.50	6.6
	2	Katagala	0.04	22.91	0.18	0.86	0.41	0.22	0.22	46.8	44.10	9.4
	3	M.Thomas	0.05	30.04	0.16	0.85	0.74	0.03	0.54	87.4	15.20	11
	4	Yasin Saidi	0.05	60.83	0.20	1.54	0.54	0.22	0.40	73.1	61.80	8.8
	5	J.Thomas	0.06	34.57	0.27	3.48	0.96	0.22	0.61	79.8	18.90	10
		Average	0.50	34.72	0.18	1.51	0.61	0.16	0.41	65.52	43.7	9.16
Urambo	1	Kasendeka	0.06	17.54	0.14	1.13	0.59	0.25	0.22	33.4	12.60	8.2
	2	Omari Yeye	0.04	16.61	0.81	0.63	0.39	0.01	0.12	38.9	18.51	8.4
	3	Kishau	0.06	23.66	0.28	1.64	0.04	0.08	0.26	59.8	8.42	10.8
	4	Hamis Utwa	0.18	5.62	0.21	4.40	1.80	0.36	0.15	12.2	17.85	21.2
	5	Myango	0.05	23.33	0.11	1.62	0.58	0.44	0.19	41.76	25.9	23.33
		Average	0.08	17.35	0.31	1.88	0.68	0.23	0.19	37.21	16.66	14.39

Table 4: Soil nutrient ranges in the tobacco growing areas of Tabora region

Nutrients	Nutrient ranges	Mean	Status
Total Nitrogen (%)	0.03 - 0.18	0.11	Low
Extractable P(mg kg^{-1})	5.60 - 60.80	33.20	Medium to high
Extractable K(me/100 g)	0.06 - 0.81	0.44	Low to medium
Ca(me/100 g)	0.01 - 4.40	2.21	Very low to high
Mg(me/100 g)	0.04 - 1.80	0.92	Very low to high
Zn(mg kg^{-1})	0.01 - 0.70	0.36	Deficient
Cu(mg kg^{-1})	0.12 - 0.97	0.55	Deficient
Mn(mg kg^{-1})	12.2 - 87.40	49.80	Deficient
Fe(mg kg^{-1})	8.42 - 78.50	43.46	Normal
CEC(me/100g)	6.40 - 23.30	14.85	Low to medium

4.2 Development of Plants in the Pot Experiment

The tobacco plants established in the pot experiment responded differently to the treatments (Plate 1). In treatment one (T1, control) plant leaves changed colour from green to yellow indicating the possibility of symptoms of nutrients deficiency in the soil. Also the leaves were thin and light, probably indicating deficiency symptom of N. However, on average 93% of the plants survived (Appendix 25). Tobacco leaves in T2 in which only nitrogen was applied, yellowing started from the apex showing interveinal chlorosis while veins were green. These are typical symptoms of Magnesium deficiency. About 96 % of the plants in this treatment survived. Leaves of Plants in T3 (Recommended rate) had normal green colour but the survival rate was less (66.7) compared with T1 and T2.

The results show further that few plants (26.7%, 13.3%, and 6.7%) established in the pots of T4, T5 and T6 respectively, survived while the rest wilted and died. The high mortality rate of plants in these treatments was probably due to high nutrients concentration including possible B toxicity in the10kg soil per pot (Herrera-Rodriguez *et al.*, 2009). Mortality rate increased from T3 to T6.

Plate 1: Treatment one, control (T1) shows acute N deficiency; Treatment two (T2: nitrogen only was applied).Slight chlorosis starting from the leaf apex with brown spots

Mortvedt (2010) reported that higher analysis fertilizers usually have a lower salt index (SI) because fewer ions of salts are placed in the soil solution per unit of plant nutrient when they dissolve. He noted that the N and K materials of commonly used fertilizers have higher SI values than those of P materials. The SI of a mixed formulation containing N, P, and/or K is the sum of the SI values of its components. Although the total SI for a high-analysis NPK mixture may be greater than that for a low-analysis NPK mixture, the SI per unit of plant nutrients may be lower in the high-analyses product. Thumma (2011) reported that, over application of inorganic fertilizer can result in damage to the root system, which can cause injury or death of the plant. Plants require more nitrogen than any other mineral nutrient found in the soil; therefore, nitrogen is often the primary ingredient in inorganic fertilizers.

Table 5: Chemical properties of soils used for the pot experiment

District	Village	Farmer	Soil type	TN (%)	P mg/kg	K	Ca	Mg	Zn	Cu	Mn	Fe	CEC
						Exchangeable cations me/100g					mg/kg		
Uyui	Ugowola	Ndindwagogo	Alfisol	0.03	24.75	0.06	0.5	0.33	0.05	0.15	27	28.28	6.4
		Thabit Hassan	Sandy soil	0.04	9.48	0.19	0.78	0.63	0.35	0.26	55.57	25.42	9.2
Tabora	Ntalikwa	Kavelele	Sandy soil	0.06	26.78	0.20	0.01	0.51	0.06	0.19	50.6	35.00	8.8
		Hamis Mwinyi	Alfisol	0.05	20.81	0.15	1.03	0.40	0.01	0.40	63.9	9.59	8.2
		Musa Mohamed	Vertisol	0.07	40.78	0.28	2.29	0.65	0.70	0.51	36.8	28.00	9.8
Sikonge	Mitowo	Katangala	Sandy soil	0.04	22.91	0.18	0.86	0.41	0.22	022	46.8	44.10	9.4
		John Thomas	Alfisol	0.06	34.57	0.27	3.48	0.96	0.22	0.61	79.8	18.90	10.0
Urambo	Yelayela	Kasendeka	Alfisol	0.06	17.54	0.14	1.13	0.59	0.25	0.22	33.4	12.60	8.2
		Omari Yeye	Sandy soil	0.04	16.61	0.81	0.63	0.39	0.01	0.12	38.9	18.51	8.4
		Hamis Utwa	Vertisol	0.18	5.62	0.21	4.40	1.80	0.36	0.15	12.2	17.85	21.2

. Too much nitrogen, however, forms salts in the soil (Thumma, 2011). These salts draw water out of the plant's roots, dehydrating it. As leaves, stems, flowers and other upper parts of the plant draw their water from the roots; they also get dry as the sun continues evaporating water from them that they cannot replace with water from the roots.

According to Thumma (2011), fertilizer burn acts on the roots and causes them to become dry and brown, the symptoms most likely to notice occurs in the leaves and other above-ground parts of the plant. Leaves wilt, then turn yellow or brown. Leaves become dry and wither and may fall from the plant.

Plate 2: Tobacco plants in pots with alfisol and sandy soils of T4, T5 and T6 after nutrients application. Some plant leaves margins were rolling down wards, followed by wilting and eventually death to the affected plants in pots

Generally the results show the mortality rate was low in the Mbuga soil with high contents of organic matter, but very high in sandy soil and Vertisol (Plate 2). This low mortality in Mbuga soils could probably be attributed to its high C.E.C and organic matter compared with the other soils. According to Spectrum analytic Inc. (2011) high soil or plant Calcium levels can inhibit B uptake and utilization. This could be another reason for plant survival against B toxicity in Mbuga soils (Vertisols). The Mbuga soil has the capacity to hold excess cations and anions in the exchange sites and hence reduce the concentration of nutrients in the soil solution and became harmless to the seedlings. Sandy soils low in clay and organic matter contents usually have fewer cations exchange sites as a result of which large amounts of nutrients were concentrated in the soil solution and became harmful to the young seedlings (Mortvedt, 2010; Thumma, 2011).

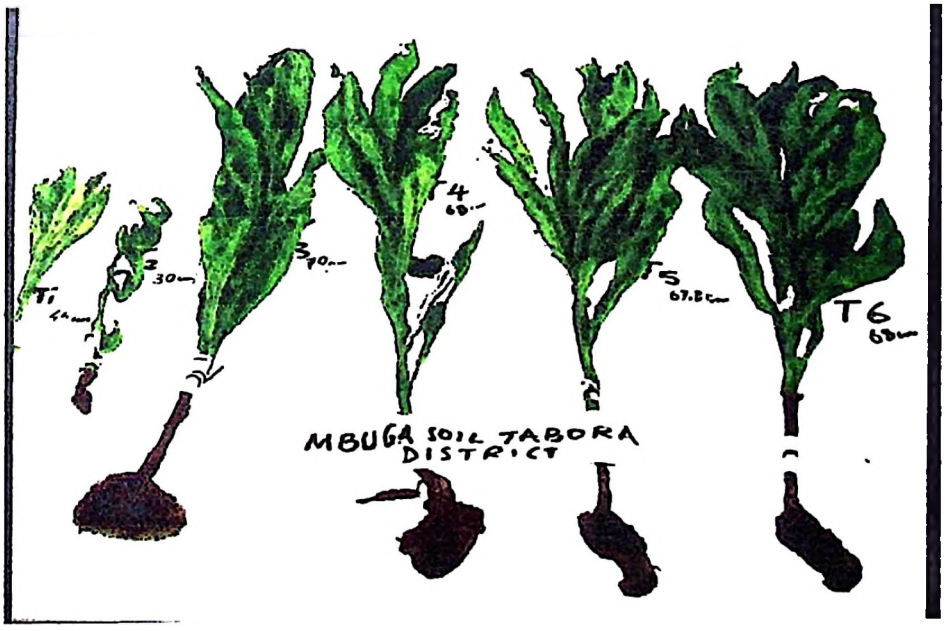

Plate 3: Tobacco plants grown in Mbuga soils (Vertisol) which survived after nutrients application. From left to right T1 (control) to T6 (highest rate of NPK+B, + Mg and Zn)

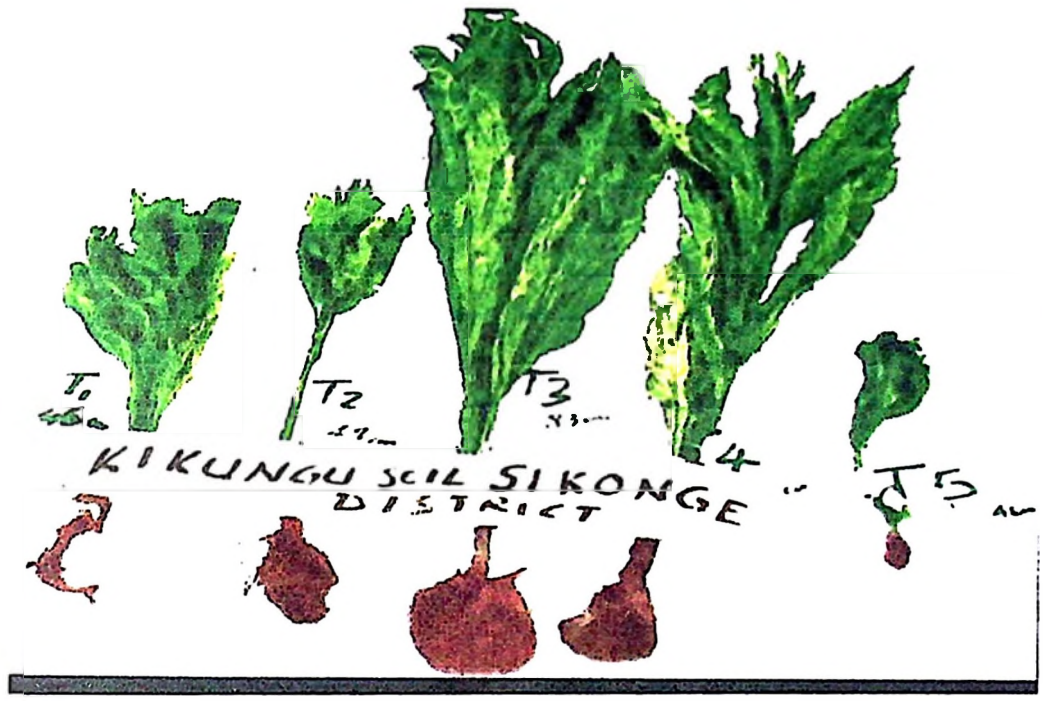

Plate 4: Plants established in Kikungu soil (Alfisol) which survived after treatments application. Plants size decreased with increase of fertilizer rate, no plant for T6.

4.3 Leaf Length as Influenced by NPK + B, Mg and Zn in the Pot Experiment

The influence of NPK+B, Mg and Zn on the length of tobacco leaves is given in Table 6. In tobacco marketing, leaf length is an important grade attribute. Long leaves which come from properly fertilized and well cured plants fulfil the desirable qualities which acquire high grades. In Tanzania tobacco grades (Appendix 28) are based on leaf length, leaf position on a stalk, colour (orange, lemon, brown) and leaf entirety. Results (Table 6) show that Isenga soils (sandy soils) and Kikungu soils (Alfisols) had longer leaves in T2 in which Kikungu soils (Alfisols) from Uyui had the longest leaves (81.0 cm).

The T2 leaves grown in Isenga soils (sandy soils) and Kikungu soils (Alfisols) were longer than T1 and T3 of all soils. It implies that the recommended N (40.5 mg k^{-1} soil) T2, was in soil solution and was readily available to tobacco plants grown in Isenga soils (sandy soils) and Kikungu soils (Alfisols). In these soils, N and other nutrients uptake was possibly influenced by relatively high aeration which allowed roots respiration (Unger and Kaspar, 1994).

In Mbuga soils (Vertisols), the longest leaves came from T3 but were not longer than those of tobacco grown in Isenga soils (sandy soils) and Kikungu soils (Alfisols). The possible reason is that N and other nutrients uptake was possibly reduced due to poor roots respiration in Mbuga soils (Vertisols) which have relatively high clay contents with few air spaces for roots respiration (Unger and Kaspar, 1994). In the same treatment (T3), Plants grown in Isenga soils (sandy soils) and Kikungu soils (Alfisols) had their leaf sizes reduced because of increase in NPK+B fertilizer which had high B content possibly affected plant growth and leaf length. When rates increased leaf size of tobacco plants grown in Mbuga soils (Vertisols) decreased while entire plants grown in Isenga soils (sandy soils) and Kikungu soils (Alfisols) died. Change of B from 3 mg kg^{-1} to 4.5 mg kg^{-1} soil and high N in T4 to T6 was harmful to plants growth including leaf length. The study by Lopez-lefebre *et al.* (2010) found that B concentration above 1 ppm was toxic to plants.

Table 6: Average tobacco leaf length (cm) by soil types in pot experiment

TREAT	UI	UK	URAI	URAK	TBI	TBK	SI	SK	MURA	MTB
1	19.5 a	37.0 b	34.0 a	36.6 a	46.6 a	39.2 b	29.7 b	37.7 ab	26.2 ab	4.3 c
2	41.0 b	81.0 a	52.7 a	43.9 a	38.6 a	73.6 a	56.9 a	65.8 a	26.3 ab	16.0 abc
3	5.3c	4.8 c	3.5 b	1.1 b	0 b	7.9 c	7.1 b	32.4 abc	53.5 a	36.7 a
4	0 c	0 c	0 b	4.4 b	0 b	0 c	0 b	11.4 bc	24.7 ab	29.4 ab
5	0 c	0 c	0 b	0 b	0 b	0 c	0 b	3 bc	30.7 ab	15.1 abc
6	0 c	O c	0 b	0 b	0 b	O c	0 b	0 c	10.8 b	10.0 bc
Mean	11.0	20.5	15.0	14.3	14.2	20.1	15.6	25.0	28.7	18.5
Lsd	10.4	5.3	19.6	16.9	19.1	18.5	20.7	35.5	35.7	24.4
CV%	52.0	20.2	71.6	64.7	73.9	50.5	72.8	78.0	68.3	72.4

Key:

UI= Uyui isenga
UK=Uyui kikungu
URAI= Urambo isenga
URAK = Urambo kikungu
TBI=Tabora isenga
TBK=Tabora kikungu
SI= Sikonge isenga
SK= Sikonge kikungu
MURA= mbuga (Vertisol) Urambo
MTB= Mbuga (Vertisol) Tabora

Similarly Post *et al.* (2004) studied development of B toxicity in barley, whereby toxicity was assessed on the basis of three criteria; root length, leaf length and extent of leaf necrosis. Growth of roots and shoots of seedlings of the B-sensitive barley cultivar Schooner were affected by B at 5 mg kg^{-1}. In addition, leaf expansion and root growth were both inhibited and the degree of necrosis was slightly more severe. He also noted boron toxicity in meristematic tissues in roots.

4.4 Dry Weight of Tobacco Leaf from the Pot Experiment by Soil Types

In this experiment seedling mortality caused the coefficient of variations to be high, and affected means separation (Table7). There were significant differences among treatments in all soils except Tabora vertisol which had no significant difference among treatments. Sikonge kikungu (vertisol) and Uyui Kikungu had the highest means (T2) that is 17.9 g and 17.3 g, respectively. The results indicate that recommended N plus residual nutrients supported the plants better than other treatments which had additional nutrients (T3 to T6) which seemed to be harmful to plants. The results therefore suggest that growing tobacco in areas where loss of nutrients (leaching or evaporation) in the soil is minimum, only small amount of additional nutrients will be required to raise tobacco plants. High rates applied (Table 1) T4 to T6 harmed young plants especially B which is toxic to plants when applied at the rate more than 3 kg ha^{-1}.

Table 7: Dry weight of tobacco leaves (g) from the pot experiment by soil type

TREAT	UI	UK	URAI	URAK	TBI	TBK	SI	SK	MURA	MTB
T1	3.0 b	10.3 b	10.1 a	4.5 b	9.2 a	8.9 b	7.0 b	3.7 b	3.4 b	1.2 a
T2	8.6 a	17.3 a	12.9 a	11.2 a	13.7 a	16.9 b	13.4 a	17.9 a	6.2 b	3.0 a
T3	1.2 b	3.4 c	1.2 b	0b	0.7 b	3.4 c	4.8 b	6.9 b	18.7 a	4.1 `a
T4	0b	0c	0b	0.89 b	0b	0c	0b	2.2 b	2.5 b	5.8 a
T5	0b	0c	0b	0b	0.15b a	0c	2.2 b	1.4 b	1.5 b	3.6 a
T6	0b	0c	0b	0b	0b	0c	0b	0b	0.7 b	0.8 a
Mean	2.1	5.0	4.0	2.8	4.0	4.9	4.2	5.4	5.5	3.1
L.s.d	1.8	5.7	5.5	2.2	4.31	5.5	5.9	9.3	7.4	4.6
CV%	65.8	63.4	90	62.5	84.5	61.9	70.9	95.5	73.9	81.7

Key:

UI= Uyui Isenga
UK=Uyui kikungu
URAI= Urambo Isenga
URAK = Urambo kikungu
TBI=Tabora Isenga
TBK=Tabora kikungu
SI= Sikonge Isenga
SK= Sikonge kikungu
MURA= mbuga (Vertisol) Urambo
MTB= Mbuga (Vertisol) Tabora

4.4.1 The effect of NPK+B, Mg and Zn on tobacco leaf nutrients concentration by soil types

4.4.1.1 Nutrients concentration in tobacco leaves grown in a Vertisol in Tabora

Table 8 shows the results of nutrient concentrations of tobacco leaves grown in dark calcareous soils (Vertisol) from Tabora districts. Nutrient concentrations in the plant leaves were determined in the laboratory and compared with sufficiency ranges (Appendix 29) prepared in the Southern region of United States of America (Campbell, 2008).

According to the results in the tobacco plant leaves analyzed N concentration was below the sufficiency range in treatments T1, and T2, (1.05 and 1.19 %) and was above the sufficiency range in T3, T4, T5, and T6. The highest concentration was in T6 (3.08%). Phosphorus was in the sufficiency range in T1, T2and T3 and it was above the sufficiency range in T4, T5 and T6, that is 0.35, 0.32 and 0.46 %, respectively. Phosphorus application was high in T3 to T6 that is why the concentration also was high (Table 8).

Table 8: Nutrients concentration in tobacco leaves grown in a Vertisol from Tabora district

Treatment combination	Concentration of nutrient in leaves						
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cu (mg/kg)	Zn (mg/kg)
T1= N_0 ,P_0 ,K_0, B_0 ,Mg_0, Zn_0	1.05	0.13	1.80	1.68	0.05	12.8	24.8
T2= N_1 ,P_0 ,K_0, B_0,Mg_0, Zn_0	1.19	0.15	1.28	2.32	0.08	7.70	14.4
T3= N_2 ,P_1 ,K_1, B_1,Mg_0, Zn_0	2.14	0.23	3.14	1.84	0.11	7.70	20.4
T4= N_3 ,P_2 ,K_2, B_2 ,Mg_0, Zn_0	2.52	0.35	5.08	1.93	0.09	7.70	25.3
T5= N_3 ,P_2 ,K_2, B_2 ,Mg_1, Zn_1	2.73	0.32	3.32	1.62	0.11	7.70	17.4
T6= N_4 ,P_2,K_2, B_2,Mg_1, Zn_1	3.08	0.46	4.02	1.84	0.16	7.70	49.7

Note: Nutrients rates for N, P, K, B, Mg and Zn.

N_0 = 0 (mg/kg) N_1= 40.5 (mg/kg) N_2=300.0(mg/kg) N_3=450(mg/kg) N_4=585(mg/kg)
P_0 = 0 (mg/kg) P_1=238.0 (mg/kg) P_2=356.4 (mg/kg)
K_0= 0 (mg/kg) K_1=598.0(mg/kg) K_2=896.4 (mg/kg)
B_0= 0 (mg/kg) B_1= 3.0 (mg/kg) B_2=4.5 (mg/kg)
Mg_0= 0(mg/kg) Mg_1=50.0(mg/kg)
Zn_0-0 (mg/kg) Zn_1=10.0 (mg/kg

Phosphorus was not applied in treatment 1 and 2, plants used the residual P from the soil only that is why the concentrations were lower than concentrations in T4 to T6 (Appendix 29).

The results in Table 8 revealed that the trend of increase of K concentration in leaves was not well defined. Treatment four gave the highest concentration of K followed by treatment six with 5.08 and 4.02% K respectively. In all treatments, K concentration was above the sufficiency range except inT1 and T2 in which no K was applied. Plants in these treatments used the residual K from the soil and the Potassium supplied from the soil was not enough to reach the sufficiency range.

The results show further that nutrient concentrations in leaves of tobacco grown in dark calcareous soil of Tabora were increasing with increases in the rate of NPK+B (10:18:24), Mg and Zn. The concentration of N, P and K were high in the treatment with the highest application rate. On the other hand, the concentration of Ca, and Cu decreased with increased NPK+B (10:18:24) rate. They were highest in treatment T1 and lowest in treatment T6. These results are in line with Gurumurthy and Vageesh (2007) who studied and reported on leaf yield and nutrients uptake by FCV tobacco as influenced by K and Mg nutrition. They observed that a high level of K decreases the Ca concentration of tobacco leaf due to antagonistic effect of Ca and Mg. They also observed that among all the nutrients absorbed from soil, K was removed in the highest amount by the tobacco crop in different positions indicating that the importance of K in mineral nutrition of flue cured variety of tobacco.

In this study, it was observed that the increase in K concentration decreased the concentration of Mg while Ca was observed to be high. Similar results were also reported

by Venkatesan *et al.* (2010) who observed that excess K application to the soil reduced the availability of Mg and vice versa, due to their antagonism. They also confirmed the synergism existing between Mg and P and noted that, Ca uptake was reduced by higher Mg input because both are divalent cations with similar ionic radius. In this case from similar mechanism the concentration of Mg appeared to be low in the treatment with high K.

In the pot experiment Ca had high concentration of up to 2.32 % in treatment two. The lowest concentration was in treatment five which was 1.62 %. In general, the range of concentration values was from 1.62 to 2.32 %. Calcium in T2 was above the sufficiency range. Results show that Mg had no defined trend in concentration. The lowest concentration was obtained from T1 in which only N was applied and nutrient concentration was below sufficiency range including T5 and T6 in which magnesium was applied. High concentration of Ca hindered uptake and hence concentration of Mg in tobacco leaves the possible reason here could be the divalent nature of Ca and Mg (Venkatesan *et al.*, 2010) which caused uptake to be below the sufficiency level.

Copper was not applied but its concentration in plant ranged from 7.7 to 11.0 mg kg^{-1}. There was no defined trend in the different treatments. In all treatments, Cu concentration was in sufficiency range which implied that plants got Cu from the soil reserve and other source like copper fungicides that were applied more than three times in the nursery to prevent fungal diseases.

Zinc concentration on other hand ranged from 14.39 to 49.65 mg kg^{-1}. The highest value was from T6 while the lowest was from T2. In general, the results disclose Zn uptake was also influenced with high NPK + B in soil.

4.4.3 Nutrients concentration in tobacco leaves grown in a Vertisol from Urambo district

Results (Table 9) show the nutrients concentration in tobacco leaves grown in a Vertisol from Urambo district. Nutrient concentrations in the plant leaves were determined in the laboratory and compared with sufficiency ranges prepared in the Southern region of United States of America (Appendix 29). The plant stage referred here is "harvest middle leaves".

Table 9: Nutrients concentration in tobacco leaves grown in a Vertisol from Urambo district

Treatment combination	Concentration of nutrients in leaves						
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cu (mg/kg)	Zn (mg/kg)
T1= N_0 ,P_0 ,K_0, B_0 ,Mg_0, Zn_0	1.89	0.10	1.32	3.23	0.19	14.40	25.8
T2= N_1 ,P_0 ,K_0, B_0,Mg_0, Zn_0	1.68	0.08	1.20	2.83	0.18	7.70	20.4
T3= N_2 ,P_1 ,K_1, B_1,Mg_0, Zn_0	1.54	0.22	2.71	1.71	0.09	7.70	12.9
T4= N_3 ,P_2 ,K_2, B_2 ,Mg_0, Zn_0	2.73	0.21	2.69	1.76	0.09	7.70	20.4
T5= N_3 ,P_2 ,K_2, B_2 ,Mg_1, Zn_1	2.24	0.27	3.05	1.93	0.12	7.70	9.4
T6= N_4 ,P_2,K_2, B_2,Mg_1, Zn_1	2.59	0.32	2.31	1.32	0.07	7.70	19.4

The results show that the highest N concentration was 2.73 % recorded from T4 and the lowest N concentration was 1.54% from T3. Treatments in sufficiency range were T1 and T2. Nitrogen concentration was slightly below sufficiency range in T3. Nutrients concentration was above the sufficiency range in T3, T4 and T6.

Results on P concentration show that the highest P concentration was 0.32% from T6; the lowest was 0.08% from T2. Treatments that had P in the sufficiency range were T3, T4 and T5. Their levels were 0.22, 0.21 and 0.27, respectively. Treatment 6 had P concentration (0.32 %) above the sufficient range. In the case of K, the highest concentration of 3.05% was recorded from T5 and the lowest was 1.2% from T2. Potassium concentration was above sufficiency range in T3, T4 and T5 that is 2.71, 2.69, and 3.05 %, respectively, while T6 was in the sufficiency range, T1 and T2 were below the sufficiency 1.32 and 1.2 %

respectively. It implies that P concentration in tobacco leaves increased with the increased rate of NPK + B, Mg and Zn.

Magnesium concentration was highest in T1 (0.19%) while the lowest Mg concentration was in T6 (0.07 %). Magnesium was close to lower limit of sufficiency range inT1 and T2 that is 0.19 and 0.18% respectively. The results revealed high K application on top of residual K decreased Mg uptake to deficiency levels. It implies that Mg and K concentration in tobacco leaves exhibited antagonistic relationship in which increase of K hinders uptake of Mg and vice versa. Gurumurthy and Vageesh (2007) observed K and Mg antagonism in their study on leaf yield and nutrients uptake as influenced by K and Mg nutrition.

The results of Zn concentration showed that the highest Zn concentration was 25.82 mg/kg from T1 and the lowest was 9.43 mg/kg from T5. Treatments in sufficiency range were T1, T2, T4 and T6, while T3 and T5 were below the sufficiency range. There was a slight decrease in Zn with increased rate of NPK + B, Mg and Zn. Presence of P at high concentration reduces the Zn uptake by tobacco plant. Similar observation was reported by Spectrum analytic Inc. (2010).

Calcium concentration in leaves was also determined. Results showed that the highest Ca concentration was 3.23 % from T1 and the lowest was 1.32% from T6. Calcium concentration existed in sufficiency range in T3, T4, T5 and T6 while T1 and T2 were above the sufficiency range 3.23 and 2.83%, respectively. Calcium concentration decreased with the increasing fertilizers rates. The possible reason could be the high concentration of NPK + B, as reported by Thumma (2011). Calcium was not applied as a

treatment but high concentration was from soil which was under maize crop which use CAN as a source of N.

The results of Cu concentration indicated that the highest concentration was 14.4 mg/kg in T1. The remaining treatments were constant at 7.7 mg/kg. In all treatments Cu concentration was in sufficiency range, this implies that plants got Cu from the soil reserve and other source like copper fungicides that were applied more than three times in the nursery to prevent fungal diseases

From the results above it can be concluded that nutrients concentrations of tobacco plants from black calcareous soil of Urambo increased with an increase in NPK+B fertilizer rates, while Ca, Mg, Cu and Zn showed the decreasing trend with increase in the fertilizer rates. These results therefore are similar to Plant analytic Inc. (2010) that reported that high levels of soil P were commonly responsible for Zn deficiencies. Results show that Zn had decreased in undefined trend. In this case, Zn decrease was probably caused by high supply of P. Presence of P at high concentration reduces the Zn uptake by tobacco plant similar observation was reported by, Plant analytic Inc. (2010).

4.4.4 Nutrients concentration in tobacco leaves grown in an alfisol from Sikonge district

Results on nutrients concentration in the alfisol in Sikonge district showed that the highest N concentration was 4.13 % from T3 and the lowest was 0.49% from T2 (Table 10). Nitrogen concentration was high in T3 in which the application was 300mg. Results revealed that high rates seemed to be harmful to tobacco plants to extent that the uptake is also negatively affected.

Table 10: Nutrients concentration in tobacco leaves grown in an Alfisol from Sikonge district

Treatment combination	Concentration of nutrient in leaves						
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cu (mg/kg)	Zn (mg/kg)
T1= N_0 ,P_0 ,K_0, B_0 ,Mg_0, Zn_0	1.3	0.20	2.2	2.4	0.16	11.1	28.8
T2= N_1 ,P_0 ,K_0, B_0,Mg_0, Zn_0	1.5	0.18	1.0	1.2	0.03	7.7	67.5
T3= N_2 ,P_1 ,K_1, B_1,Mg_0, Zn_0	4.1	0.30	3.7	1.3	0.21	11.1	61.1
T4= N_3 ,P_2 ,K_2, B_2 ,Mg_0, Zn_0	2.0	0.20	2.8	1.3	0.13	7.7	32.8
T5= N_3 ,P_2 ,K_2, B_2 ,Mg_1, Zn_1	1.7	0.35	3.1	1.3	0.08	7.7	9.4

Phosphorus concentration was in sufficiency range in T1, T2, T3 and T4 that is 0.2, 0.18, 0.3 and 0.2, respectively. On the other side, T5 was above the sufficiency range 0.35%. The nutrients trend here is not clearly defined.

Results in Table 10 show the highest K concentration in T3 was 3.67% while the lowest was 1.04 % from T2. The treatment which had the K concentration below sufficiency range was T2 while T1 was in sufficiency range, however T3, T4 and T5 (3.67, 2.8 and 3.14%) were above the sufficiency range.

Potassium rate applied was 598 mg kg^{-1} for T3 while 896.4 mg kg^{-1} were applied to T4, T5 and T6.In this case T3 was the optimum for K in the pot experiment because the application was lower than T4, T5 and T6 but it had high K concentration. The possible reason could be that, plants were not affected by high nutrients concentration from high fertilizer rates and therefore they maximized K uptake and eventually the concentration was high.

The highest Mg concentration (Table 10) was 0.21% from T3, while the lowest was 0.03 % from T2. Magnesium concentration in sufficiency range was in T3 only. The remaining treatments were below the sufficiency although the trends were not clearly defined.

Magnesium was not applied in T1, T2, T3 and T4 but the highest concentration was in T3. The possible reason could be, high P applied influenced Mg uptake because of the synergism between Mg and P. Plants in T3 were note subjected to salt environment because of high nutrients from high fertilizers rates therefore nutrients uptake was optimum (Venkatesan *et al.*, 2010).

Results on Zn concentration showed that the highest Zn concentration was 67.53 mg kg^{-1} from T2 and the lowest was 9.43 mg kg^{-1} from T5. Zinc concentrations were in sufficiency range in leaves of T1 and T4 i.e. 28.79 and 32.77 mg kg^{-1}, respectively while T5 was below the sufficiency range and T2 and T3 were above the sufficiency range (67.53 and 61.07 mg kg^{-1}). Zinc concentration was possibly reduced because of presence of high P rates (Plant analytic Inc., 2010).

The highest Ca concentration was 2.35 % from T1 and the lowest was 1.17% from T2. All treatments had Mg values in the sufficiency range. In general, the results indicate that Mg concentration trends from tobacco grown in vertisol from Sikonge were at the peak in T3. NPK + B increased up to T3 which is the current fertilizer rate and then decreased as the NPK+B rates increased. Regardless of the stresses, nutrients concentrations were at the optimum on T3. The results, therefore, suggest that increases in nutrients beyond T3 resulted to unfavourable nutrients solution which is harmful to young plants.

4.5 Tobacco Leaf Grade Indices from Pot Experiment by Soil Type

Tobacco quality can be judged by the grade index. The higher the grade index of cured leaves reflects higher quality of cured tobacco leaves. Results (Table 11) show that cured leaves from sandy soil of Uyui (T3) gave the highest grade index (35.0) , followed by

sandy soil of Tabora (33.3) in the same treatment. The lowest grade index was from T1 of alfisol (1.7).

Reasons for high quality leaves from Uyui and Tabora sandy soil were addition of the recommended rate of NPK +B (10:18:24 +0.1) 30g per plant. The applied fertilizer increased the amount of N, P, K and B in the soil hence boosted the function of those essential nutrients in plants after uptake from the soils. The results therefore suggest that the amount of NPK + B improved quality of the tobacco leaves. Potassium is always responsible for quality improvement in tobacco. The quality parameters that are related to K are physical appearance and burning quality (Ikisan.com, 2000). Nitrogen did not last longer in Isenga soils (Sandy soils) therefore N did not cause problems in tobacco leaves curing. Reduced nitrogen level also makes flue cured tobacco curing easy. Therefore it was easy to cure tobacco in low N level than high N levels which eventually give poor tobacco grades (Ikisan, 2000). Excessive fertilizers in pots negatively affected crop growth and quality. In T 4, T5 and T6, nitrogen was high and resulted in leaf quality reduction.

Sikonge Kikungu soils (Alfisols) had the highest grade index of all Kikungu soils (Alfisols), the possible reason is high K (3.7 %) in leaves. Potassium influences quality in tobacco leaves. The highest grade index in Mbuga soils came from T3 (the recommended), which had high average K (3.0 %).

Table 11: Grade indices of tobacco leaves from the pot experiment

Treatment	UI	UK	URAI	URAK	TBI	TBK	SI	SK	MURA
T1	20.3 a	21. 5 a	14.0 a	17.7 a	19.0 a	21.1 a	9.4 a	16.2 a	3.4 bc
T2	21.7 a	23.4 a	9.0 a	11.0 a	20.8 a	20.5 a	25.4 a	18.0 a	2.7 c
T3	35.0 a	12.8 a	0	0	33.3 a	23.7 a	19.5 a	15.6 a	23.5 ab
T4	0	0	0	0	0	0	0	31.49 a	23.5 ab
T5	0	0	0	0	0	0	0	0	25.9 a
T6	0	0	0	0	0	0	0	0	0
Mean	22.97	20.0	11.46	14.36	17.49	23.01	18.23	18.40	16.12
L.S.D	28.19	29.5	31.44	26.43	21.81	39.40	31.61	56.30	22.26
CV%	31.25	57.3	121.0	81.2	31.16	38.04	38.04	84.30	30.68

4.6 Field Experiment

4.6.1 Soil Characteristics

The field in which the experiment was carried out is located at Ntalikwa village. The field is owned by Seleman Kavelele. The farm has sandy soil. The chemical characteristics of the soil are presented in Table 3. The results show that total N was very low (0.06 %), extractable P (Bray-1) was 26.78 mg/kg, the exchangeable K was 0.2 mg/kg, Mg was 0.51 mg/kg, Zn was deficient (0.06 mg/kg), Ca was deficient (0.01 mg/kg), Mn 50.6 mg/kg, Fe 35 mg/kg, Cu was 0.19 mg/kg and CEC was 8.8 mg/kg.

4.6.2 Plants performance in the field experiment

The results showed that crop performance was good in almost all treatments. Plant population was 264 plants/ha after transplanting. Plant survival was 96 %. Responses to the different treatments were according to the rate of nutrients applied as can be seen in Plate 5 and 6. Tobacco leaves from plants in control plots (T1) matured quickly possibly because of N deficit (Plate 5) compared with T6. Plots with higher rates of N caused tobacco leaves to be dark green (Plate 6) which delayed maturity.

4.6.3 Leaf length as influenced by NPK + B, Mg and Zn

The effect of NPK B, Mg and Zn on leaf length under field conditions was shown in Table 11. Leaf length increased with increasing levels of NPK plus B. Incorporation of Mg and Zn enhanced increases in leaf length. Khan *et al* (2008) reported significant increases in leaf yield of flue cured tobacco with increased fertilizer application (N, P_2O_5 and MgO). According to the authors maximum percentage of top quality leaves was obtained at higher dosages of Zn fertilization. On the other hand, deficiency of B resulted in extreme turgidity and breakage of the midribs of the leaves. It was also argued that micronutrients play vital roles in plant nutrition and are essential for various enzymatic reactions and metabolic

processes as was observed in this study, application of the fertilizers increased leaf lengths possibly through the roles those nutrient elements played in different enzymatic reactions and metabolic processes (Table 12).

Plate 5: Tobacco plants in treatment one (control) showing yellowing of immature leaves due to N deficiency

Field experiment results showed further that there was no significant difference among all treatments with respect to bottom leaves ($P > 0.05$). T1 had the highest mean number of bottom leaves when compared with other treatments although statistically the difference was not significant. The possible reason could be that residual nutrients in the soil were utilized first in the development of bottom leaves, which grew to the maximum size but these nutrients were not enough to allow for maximum growth of middle and top leaves in T1 as a result it differed significantly from T2, T3, T4, T5 and T6 (Table 12). On middle and top leaves, lengths increased with increasing levels of NPK+B, Mg and Zn applied.

Plate 6: Tobacco plants in treatment six; showing large and greener leaves with other light yellow ripe leaves

The results are in agreement with those of Martin-ortiz *et al.* (2009). In which application of NPK, boron and zinc to flue cured tobacco increased growth and yield. It can also be noted from Table 12 that T2, which was supported by residual nutrients plus replenishment had greater leaf length than T1, which was the control (Table 12). In view of this, it is evident that the soil type in the experimental field can be improved greatly if nutrients supply is done to replenish the removed nutrients in the previous seasons. The highest means for top and middle leaves were from T5 and T6, with leaf lengths of 54.6cm and 61.5 cm, respectively. However T5 and T6 were not significantly different from T2 ($P < 0.05$), which suggest that the recommended N (80.5 kg ha^{-1}) and the added P (10 kg ha^{-1}) caused tobacco plants to produce longer leaves almost similar to those supplied with high rates of N in T3 to T6.

Table 12: Leaf length from field experiment as influenced by NPK + B, Mg and Zn

Treatment combination	Bottom leaf (cm)	Middle leaf (cm)	Top leaf (cm)
T1= N_0 ,P_0 ,K_0, B_0 ,Mg_0, Zn_0, Cu_0	27.5 a	47.0 b	40.70 b
T2= N_1 ,P_1 ,K_1, B_0,Mg_0, Zn_1, Cu_1	25.4 a	58.4 a	49.2 a
T3= N_2 ,P_2 ,K_2, B_1,Mg_0, Zn_0, Cu_0	25.9 a	60.3 a	52.3 a
T4= N_2 ,P_2 ,K_2, B_1 ,Mg_1, Zn_1, Cu_0	25.9 a	60.4 a	52.4 a
T5= N_3 ,P_3 ,K_3, B_2 ,Mg_2, Zn_2, Cu_0	26.5 a	61.2 a	50.9 a
T6= N_4 ,P_4 ,K_4, B_3,Mg_2, Zn_2, Cu_0	26.6 a	61.5 a	54.6 a
Mean	26.30	58.12	50.04
L.S.D.	3.12	7.85	7.57
CV%	6.5	7.4	8.3

Note: Nutrients rates for N, P, K, B, Mg, Zn,

N_0 = 0 kg/ha	N_1= 80.2kg/ha	N_2= 72.5 kg/ha	N_3=75 kg/ha	N_4=100 kg/ha
P_0 = 0 kg/ha	P_1= 10 kg/ha	P_2= 39.6 kg/ha	P_3=59.4 kg/ha	P_4= 79.2 kg/ha
K_0= 0 kg/ha	K_1=53.12 kg/ha	K_2= 99.6 kg/ha	K_3=149.4 kg/ha	K_4=199.2 kg/ha
B_0= 0 kg/ha	B_1= 0.5 kg/ha	B_2=0.75 kg/ha	B_3=1.0 kg/ha	
Mg_0= 0 kg/ha	Mg_1= 50 kg/ha	Mg_2=100 kg/ha		
Zn0 = 0 kg/ha	Zn_1 = 5 kg/ha	Zn_2= 20 kg/ha		
Cu0=0 kg/ha	Cu_1=2.5 kg/ha			

4.6.4 Green weight, dry weight, and leaf grade index as influenced by NPK + B, Mg and Zn under field conditions

Application of NPK+B, Mg and Zn in this study showed that different combinations of nutrients significantly ($P< 0.05$) increased green and dry weight yield of tobacco leaf when compared with the control (Table 13).

4.6.4.1 Green leaf yield

Different levels of NPK+ B, Mg and Zn significantly increased green leaf yield (Table 13). Maximum yield was obtained by applying 100, 79.2, 199.2, 1.0, 50, and 5 kg ha^{-1} of N, P, K, B, Mg, and Zn, respectively while minimum values were recorded from control plots. These results are logical, given that B is an essential element for the development and growth of plants and that it is the determinant in such fundamental process as cell elongation and division or nucleic acid metabolism and enhance

nutrients uptake. Lopez-Lefebre *et al.* (2002) also reported that macronutrients (N, P, K) responded positively to dosage of NPK and B.

Table 13: Green weight and dry weight for the field experiment

Treatments	Green weight ($kgha^{-1}$)	Dry weight ($kgha^{-1}$)
$T1= N_0, P_0, K_0, B_0, Mg_0, Zn_0, Cu_0$	7218.52 b	1411.89 b
$T2= N_1, P_1, K_1, B_0, Mg_0, Zn_1, Cu_1$	9468.86 ab	1888.81 ab
$T3= N_2, P_2, K_2, B_1, Mg_0, Zn_0, Cu_0$	11118.49 a	2190.19 a
$T4= N_2, P_2, K_2, B_1, Mg_1, Zn_1, Cu_0$	11526.14 a	2077.94 a
$T5= N_3, P_3, K_3, B_2, Mg_2, Zn_2, Cu_0$	11487.63 a	2254.40 a
$T6= N_4, P_4, K_4, B_3, Mg_2, Zn_2, Cu_0$	13067.73 a	2488.12 a
Grand mean	10647.89	2051.89
L.S.D	3521.35	583.21
CV %	18.2	15.60

4.6.4.2 Dry leaf yield

Different levels of NPK+ B, Mg and Zn significantly affected dry cured leaf yield (Table 13). Maximum yield was obtained from T6 after applying 100, 79.2, 199.2, 1.0, 50, and 5 kg ha^{-1} of N, P, K, B, Mg, and Zn respectively while minimum values were recorded from the control plots.

The high yield was contributed to greater growth which resulted from the positive effects of B application which improved uptake of the essential macronutrients N, P and K (Lopez-Lefebre *et al.*, 2002). Gurumurthy and Vageesh (2007) observed that application of K and Mg improved nutrients uptake and yield of flue cured tobacco that is probably the reason why treatment 6 which had high rates of the elements, had high yield too.

The results revealed that there was an increase of both green and dry leaf yields from T3 to T6 although the increase was not significantly different. Green leaf weights were11.12, 11.53, 11.49, and 13.07 t ha^{-1} for T3, T4, T5 and T6, respectively while the weights of dry leaf were; 2.19, 2.08, 2.25, 2.49 t ha^{-1} for T3, T4, T5 and T6, respectively.

This study revealed that NPK plus B, Mg and Zn led to relatively higher yield compared with the control treatment (Plate 6). Khan *et al.* (2008) similarly recorded higher yields as affected by different levels of fico micron and boron in which maximum yield (2948 kg ha^{-1}) was obtained at fico micron (8.6, 9.2 and 11.8 kg of Zn, Cu, and Mg, respectively) 40 kg ha^{-1} and 10 kg B ha^{-1}. The authors reported that application of Mg, Zn or B fertilizers at transplanting and foliar application during the growing season increased leaf chlorophyll concentration, photosynthesis and yield of cured leaves. These findings are in agreement with the current study where increasing levels of NPK with B, Mg and Zn increased yield. Maximum leaf yields were from T6 for both green and dry leaf weight (13 067.73 kg ha^{-1} and 2 488.12 kg ha^{-1} , respectively). It was evident that N levels below the recommended rate (80.5 kg ha^{-1}) together with recommended levels of P, K and B i.e. 39.6, 99.6 and 0.5, respectively with CAN (83.3 kg ha^{-1}) in T3 and T4 gave yields which were statistically equal to T5 and T6 which had 75 and 100 kg N ha^{-1} . The results revealed that Ca in CAN as source of N plays a role on yield determination in Tobacco.

4.7 Nutrients Concentration in Tobacco Leaves

Results on effect of NPK+ B, Mg and Zn on nutrient concentration in tobacco leaves under field conditions (Table 14) were compared with the sufficiency ranges for flue cured tobacco grown in the Southern Region of the United States of America (Capmbell, 2009). There were significant ($P< 0.05$) differences in N concentration among treatments and the control. However differences among other treatments were not significant. The concentration of N ranged from below to sufficiency range (1.4 to 2.05%). Treatment 5 had the highest concentration of N, the same as T4, followed by T6. Plants in T1 used residual nitrogen only from the soil. There were reduced nutrients concentrations in the control compared with other treatments.

Phosphorus concentrations were not significantly different among treatments but the highest concentration was from T6 (0.17%) while the lowest was from the control (0.12%). Treatment one (control) was below the sufficiency range while others were within the sufficiency range. This indicated that the residual P in the control plots was not sufficient to allow plants to take up P in the sufficient range such as in leaves of plants from T2 to T6. Phosphorus in the sufficiency range is always important for normal functioning of plants(Spectrum Analytic Inc., 2010).

Table 14: Nutrient concentrations in tobacco leaves as influenced by NPK + B, Mg and Zn in the field experiment

Treatment combination	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	Zn mg/kg	Cu mg/kg
T1= N_0 ,P_0 ,K_0, B_0 ,Mg_0, Zn_0, Cu_0	1.4b	0.12a	1.4a	0.19a	1.4 b	7.3 b	7.73
T2= N_1 ,P_1 ,K_1, B_0,Mg_0, Zn_1, Cu_1	2.0a	0.15a	1.6a	0.15a	3.0 a	12.1 b	7.73
T3= N_2 ,P_2 ,K_2, B_1,Mg_0, Zn_0, Cu_0	2.0a	0.15a	1.8a	0.20a	2.4 ab	8.3 b	7.73
T4= N_2 ,P_2 ,K_2, B_1 ,Mg_1, Zn_1, Cu_0	2.2a	0.15a	2.3a	0.18a	2.5 ab	27.8 a	7.73
T5= N_3 ,P_3 ,K_3, B_2 ,Mg_2, Zn_2, Cu_0	2.2a	0.13a	2.1a	0.20a	2.7 ab	11.3 b	7.73
T6= N_4 ,P_4 ,K_4, B_3,Mg_2, Zn_2, Cu_0	2.1a	0.17a	2.0a	0.19a	2.4 ab	18.2 ab	7.73
Mean	2.0	0.14	1.9	0.18	2.4	14.1	7.73
LSD	0.4	n.s.	n.s.	n.s.	1.4	11.7	-
CV%	6.4	31.15	13.1	19.78	32.6	45.5	-

The concentration of N was not in the sufficient range showing that although there were residual nutrients in the soil, N amount was not sufficient for tobacco. Results show that K was within the sufficiency range in all treatments except from T1 and that there were no significant differences among treatments ($P < 0.05$). The highest K was from T4 while the lowest was from T1. The results imply that even though the soil had residual K, it was not enough to fulfill requirements of the tobacco plants. There were no significant differences in concentrations of K between the control and other treatments implying that K was available in the soil as residual nutrient.

In case of Mg it was like P and K. There was no significantly difference between the control and the rest of the treatments in concentration. The results indicate that Mg concentrations in T2 to T6 fit in the sufficiency range. In this case application of NPK+ B, Mg and Zn had small effects on Mg although Mg and K antagonism is shown in treatments which were slightly below the sufficiency range (T2, T3, and T6). High K reduces Mg uptake and eventually low Mg concentration in the leaves. There is no defined trend of Mg with the increase of NPK+ B, Mg and Zn (Table 14).

Calcium sufficiency range is 1.0 to 2.0 % (Appendix 28). Calcium concentration values in tobacco leaves ranged from 1.4 to 3.02 %. All treatments had leaves with Ca concentration values above the sufficiency range except for T1. The highest concentration was from treatment two 3.02% (Table 14) and the lowest was from T3 (2.36%). There was no significant difference among treatments. According to Spectrum analytic (2011). Soluble P is an anion, meaning it has a negative charge. Any free Ca reacts with P to form insoluble (or very slowly soluble) Ca-P compounds that are not readily available to plants. As the pH of a soil decreases, more of Fe^{++} and Al^{+++} become soluble and combine with Ca to form essentially insoluble compounds. Therefore, calcium recovery from non exchangeable form to exchangeable form could have made more Ca to be available to plants.

Results (Table 14) show that there were significant differences in Zn concentration between T3 and other treatments including the control (T1). Treatment four and six only were in the sufficiency range. The rest of the treatments were below the sufficiency range. Increased NPK+ B, Mg and Zn had effects in Zn concentration because there were increases, in Zn concentration from T1 to T4 and then slight increase in concentration in T6. The optimum Zn concentration was in T4 (27.8%) in treatment combination of 72.2

kg N ha^{-1}, 39.6 kg P ha^{-1}, 99.6 kg K ha^{-1}, 0.5 kg B ha^{-1}, 50 kg Mg ha^{-1}, 5 kg Zn ha^{-1} (Table 14).

Results indicate that treatments without Zn, the concentration of Zn was low and deficient where Zn was applied Zn concentration increased to sufficiency level except for T5 and T2. Data suggest a response to Zn but the trend is a bit inconsistent. However, considering the low level of Zn in the soil, data indicate the need for Zn supplementation.

Copper occurred in deficient level in the field experiment sandy soil (0.19 mg kg^{-1}) but it was found in sufficiency range (7.73 mg kg^{-1}) in all treatments regardless of T2 in which it was applied. The possible reasons for the occurrence of sufficient copper in all treatments is the routine application of copper fungicide to tobacco when established in the nursery for eight weeks and also areas located for nursery for raising tobacco seedlings have high possibility of having high levels of Cu because of continuous application of cooper fungicides to control fungal diseases for years.

4.6.4.3 Grade index of leaves

Application of NPK + B, Mg and Zn influenced grade index except for treatment 2 which had the lowest grade index than the control (15). In this study, it was difficult to cure tobacco from T2 to T6 because of the delay in ripening which made the curing stage to coincide with the dry weather period in the season. Greenish colour in tobacco leaves are given low grades in a market and resulting in low grade index.

It should also be noted that the control (T1) had the highest grade index (1.55) but it was statistically not significant from T3, T4, T5 or T6 though it was statistically different from T2. On the other hand T2 did not differ significantly from T3, T4, T5 or T6. It implies that

plants in the control treatment had low nutrients supply from the soil and hence maturity was faster and almost the entire leaves yellowed even before picking which meant yellowing was no longer a problem in T1 leaves in curing process.

Table 15: Leaf grade index for the field experiment

Treatments	Grade index
T1= N_0 ,P_0 ,K_0, B_0 ,Mg_0, Zn_0, Cu_0	1.55 a
T2= N_1 ,P_1 ,K_1, B_0,Mg_0, Zn_1, Cu_1	0.67 b
T3= N_2 ,P_2 ,K_2, B_1,Mg_0, Zn_0, Cu_0	1.05 ab
T4= N_2 ,P_2 ,K_2, B_1 ,Mg_1, Zn_1, Cu_0	1.41 ab
T5= N_3 ,P_3 ,K_3, B_2 ,Mg_2, Zn_2, Cu_0	1.04 ab
T6= N_4 ,P_4 ,K_4, B_3,Mg_2, Zn_2, Cu_0	1.17 ab
Grand mean	1.15
l.s.d.	0.79
cv%	37.89

The most unwanted colour is green and it is given very low grade in the market. In this case, tobacco in T1 was lemon in colour, which is tolerated compared with green colour. On the other hand, the N levels in the rest of the treatments were high. As a result of this, yellowing stage was prolonged and curing was difficult. Normally, heavily fertilized tobacco tends to retain green colour which is difficult to cure if the weather condition is dry (Ikisan.com, 2009). Also under the National Classification Standard, tobacco with green colour is given low grade which leads to low grade index (Appendix 28). Murthy *et al.* (2006) reported that, large amounts of nitrogen applied to tobacco was the reason for dark-green colour persistency in leaves, and delayed ripening. Cured leaf was dark, trashy, thick and immature.

Apart from the control, treatment 4 had high grade index (1.41) and it did not significantly differ with T1. Results show that T4 had N, P, K, Mg, Ca and Zn in sufficiency range and possibly confirm that high grade index of T4 was influenced by these nutrients. Treatment

1 had N, P, K, Mg, and Zn below the sufficiency range and the grade index was influenced by external appearance of leaves.

4.8 Comparison between Pot Experiment and the Field Experiment

The pot experiment and field experiments had similar treatments with nutrients rates applied which were equivalent arithmetically. The differences and similarities of the treatments' responses of the two experiments are discussed below.

4.8.1 Plant condition

Pot experiment was carried out in a screen house in which air circulation and enough light was allowed. Good plant survival in the pot experiment (Appendix 25) was recorded from dark calcareous soils of Urambo and Tabora. The Kikungu (Alfisol) soil of Sikonge had better survival than Isenga soil (low land sandy soil). Plants in the pot experiment had poor growth, wilted and dried up from treatment 4 to 6. The condition was severe in Isenga soil (sandy soil) of all districts, Alfisol of all districts except Sikonge. Vertisol of Urambo, Tabora and Alfisol of Sikonge had good survival although the plants were reduced in growth and size with the increase of fertilizer rates.

Similar nutrients were applied to the plant in the field and plant survival was good (Appendix 26). The possible reason for good plant survival in the field was huge amount of soil in the field that in 30 m^2. The mass of soil was 6 tonnes for 50 plants per plot or 120 kg of soil per plant (including the soil below 20 cm slice) possibly helped to buffer the side effects of the high nutrients concentration. In pot experiment there was 10 kg of soil per plant confined in a pot. There was a possibility that high concentration of nutrients in pot caused root injury.

4.8.2 Leaf length

Tobacco leaves in the field experiment were long and large in size compared with the pot experiment (Plates 1 and 6). The longest leaves were from T6 of field experiment while the longest leaves in pot experiment were from T2. The observed differences were due to the fact that the pot experiment was in the screen house in which light interception by tobacco leaves was lower than the field experiment which was exposed to full solar radiation. Tobacco in the pot experiment had relatively narrow and light leaves because light interception by tobacco leaves was low. In this case, photosynthesis was more effective in tobacco plants in the field experiment as compared with pot experiment.

4.8.3 Yield

Plants in the pot experiment had lower yield compared to the field experiment. Tobacco in the field experiment had better plant survival and was exposed to maximum solar radiation and had maximum photosynthesis and hence high biomass build up. The highest dry leaf weight was from the field experiment with T6 (2 488.12 kg ha^{-1}) while the highest yield from the pot experiment was from T3 of Urambo Mbuga (Vertisol) which produced 18.7 g per pot.

4.8.4 Nutrients concentration

Potassium uptake for both field and pot experiments was high, followed by N. In the field experiment the mean concentration of Mg (0.18%) from sandy soil (0.51 mg kg^{-1}) was higher than Mg concentration in leaves of tobacco grown in Mbuga soil (Vertisol) of Tabora in which T6 had the highest value (0.16%), but less than Mg from leaves of tobacco grown in Kikungu soil (Alfisol) of Sikonge T3 (0.21%) and also slightly less than leaves of tobacco grown in Mbuga soil (Vertisol) of Urambo T1 (0.19%) as shown in Table 8, 9 and 10. Results in Table 3 show that soils from Kikungu soil (Alfisol) of

Sikonge (farmer no.15, 0.96 mg kg^{-1}). Mbuga soils (Vertisols) from Urambo (farmer no.19, 1.8 mg kg^{-1}) had soils which had higher Mg content than soil in the field experimental area.

Zinc concentration was high in T4 (27.8%) in the field experiment while in pot experiment the highest concentration was in T6 for tobacco leaves grown in Mbuga soil (Vertisol) of Urambo (Table 9) was in T1 (25.8%). Zinc concentrations in T1, T2, T3 and T4 with values 28.8, 67.5, 61.1 and 32.8 respectively of tobacco leaves grown in Kikungu (Alfisol) of Sikonge were higher than the field experiment; T5 had the lowest concentration, in the pot experiment was 9.4 % (Table 9 and 10). Zinc concentration in leaves of tobacco grown in Mbuga soil (Vertisol) of Tabora and Urambo was low because of low level of Zn in the soil. High concentration of Zn in Kikungu soil (Alfisol) was possibly due to Zn from soil was higher than field experimental site (0.25 mg kg^{-1}) which means the available and the added were confined in the soil solution in the pot and were taken by tobacco plants.

4.8.5 Grade index

Grade index (across treatments) for pot experiment showed a different trend from the field experiment. Treatment 4 of Kikungu soils (Alfisols) from Sikonge had the highest Grade index which was contributed by high K (2.8 %), sufficient N (2%), P (0.2%), and Ca (1.3 %) Zn (32.8 %) and Cu (7.7 %). Grade index was high in T5 of Mbuga soils (Vertisols) as seen in Table 11. Nutrient concentrations showed that K was high (3.05 %) above sufficiency range, while Mg was below the sufficiency range. Nutrients in and above the sufficiency range contributed to the high grade index in T5 because grade index increases with increase in nutrients.

The treatments in the field experiment increased grade index except for treatment 2 which was less than the control (Table 15). It should also be noted that the control treatment (T1)

gave the highest leaf grade index. Tobacco with low nitrogen is cured easily compared with tobacco with high nitrogen concentration in leaves at leaf maturity (Ikisan.com, 2009). Apart from the control, treatment 4 had high leaf grade index (1.41) and it did not significantly differ from T1. According to the results show that T4 had N (2.2 %), P (0.15%), K (2.3%) , Ca (2.5 %) and Zn (27.8%) were in sufficiency range and possibly verify that high leaf grade index in the treatment was influenced by these elements. Treatment 1 had N, P, K, Mg, and Zn below the sufficiency range and the grade index was influenced by yellow appearance of leaves which is one of grade in the attributes in tobacco classification.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Evaluation of residual levels of nitrogen, phosphorus, potassium and boron in selected tobacco growing areas of Tabora region

From the findings of this study it can be concluded that total nitrogen in all sites ranges from very low to low (0.03 to 0.18%) implying that N fertilizer is required in all sites tested. Available phosphorus is medium (5.62 to 60.83 mg/kg soil). Exchangeable potassium ranges from low to very high (0.06 to 0.81), exchangeable calcium ranged from 0.01 to 4.40 which was rated as very low to high. About 80 % of the soils have values below the mean value (2.21 me/100 g), Magnesium levels ranged from very low 0.04 to medium 1.8 me/100g soil. The cation exchange capacity (CEC) of the soils was low; 6.4 to medium 23.33 me/100g soil.

The recommended rate of NPK plus B (T3) had low performance in nutrients uptake and dry leaf yield compared to the newly tested formulations of T4, T5 and T6 in the field experiment although the latter treatments were not statistically. Treatment 6 was the best of all treatments in terms of yield whereas T5 was the optimum in leaf yield and quality.

5.1.2 Adequacy of NPK + B (10:18:24 +0.1) for tobacco production

The formulation with NPK+ B alone was not adequately meeting the tobacco plant nutrients requirements. In the field experiment, the recommended rate NPK + B 10:18:24 +0.1 applied was not enough because key nutrient elements were very low in the soils of tobacco growing area of Tabora. The recommended NPK + B 10:18:24 +0.1 (treatment 3),

yield was below treatment 4, 5, and 6 which had high rate of N, P, K+ B and different rates of Mg and Zn which improved yield per hectare.

5.1.3 To determine the effects of the current NPK and B formulation on yield and quality of tobacco

In this study the best combination was treatment 4 which involved 72.5 kg N ha^{-1}, 39.6 kg P ha^{-1}, 99.6 kg K ha^{-1}, 0.5 kg B ha^{-1} , 50 kg Mg ha^{-1} and 5 kg Zn ha^{-1}. This combination provided yield which was not significantly different from T6 which was the highest. It had grade index which was high and none significantly different to T1 which had also high index but lowest yield. The concentration of N, P, K, Mg, Ca, Zn and Cu were in the sufficient range compared with all other combinations.

The higher levels are unfavourable because, large amount of nutrients are applied and cause imbalance or toxicity which interferes with uptake and utilization of other nutrients. Some nutrients, if applied in excess, are fixed in the soil and not utilized by the plants immediately, for example P and K. High rates cost more than low rates while not all nutrients are used by the tobacco plant and reduced the profit margin to farmers.

The current NPK+B 10:18:24 +0.1 was inadequate for flue cured tobacco production because the new tested formulation which had Mg and Zn gave higher yield and quality compared with the current formulation. Magnesium and zinc are deficient and when applied the concentration increased to sufficiency range for Zn and close sufficiency range for Mg. consequently improved yield and quality.

5.2 Recommendations

1) There is a need to improve tobacco yield and quality through routine soil fertility status assessment. The current soil fertility status needs new fertilizers formulation in order to obtain the right combination and proportions of macronutrients and micronutrients which will improve tobacco yield and quality. The major goal of a tobacco fertilization programme should be to avoid excessive nutrients application to tobacco field while providing sufficient nutrients to maintain a vigorously growing crop.

2). Field experiment showed that NPK +B, Mg and Zn had good performance in sandy soil with low fertility. Treatment 4 which combines 72.5 kg N ha^{-1}, 39.6 kg P ha^{-1}, 99.6 kg K ha^{-1}, 0.5 kg B ha^{-1} , 50 kg Mg ha^{-1} and 5 kg Zn ha^{-1}, could be the optimum treatment to be applied to flue cured tobacco to replace the current treatment used by farmers in the tobacco growing areas of Tabora.

3). Based on the results obtained in this study, the current fertilizer formulation for tobacco production should include Mg and Zn as these elements showed great potential in improving tobacco yield and quality.

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APPENDICES

Appendix 1: Reduction in phosphorus application on N.C. flue-cured tobacco

Year	P_2O_5 (million kg)	P_2O_5 (kg/ha)
1979	11.06	207.39
1980	10.08	164.79
1981	9.01	147.97
1982	7.13	137.88
1983	5.61	133.40
1984	6.15	144.61
1985	4.63	114.34
1986	3.46	100.89
1987	3.55	96.41
1988	3.77	94.16
1989	3.71	86.32
1990	4.17	91.92

Source; NCDA Fertilizer Tonnage Reports. (2007)

Appendix 2: Nutrient Removal by Crops in North Carolina Nutrient Removal by Crops in North Carolina

Flue cured tobacco	yield/ha	N	P_2O_5	K_2O	Ca	Mg	S	Cu	Mn	Zn
Leaves	3363	38.46	6.79	70.14	33.94	6.79	5.43	0.01	0.25	0.03
Stalks	4036	18.55	4.98	46.15	*	4.07	3.17	*	*	*

* symbol means the information was not available in the reference used.

Source: NRCS (2007).

Appendix 3: Interpretation of the boron soil test

Soil texture	Very low	low	High	Excessively very high
	B (ppm)			
Sands, loam sands	< 0.2	0.3 – 0.4	1.2 – 2.5	>2.5
Sandy loams, loams, silt loam, Silt clays	< 0.3	0.4 – 0.8	1.6 – 3.0	>3.0
Mucks, Peats	< 0.5	0.6 – 1.0	2.1 – 4.0	>4.0

Source: University of Wisconsin System board of regents and University of Wisconsin Extension, Cooperative Extension (1994).

Appendix 4: Micronutrients uptake by rice

Treatments	Uptake (mg^{-2})			
	Zn	Cu	Fe	Mn
Control	22	2.2	238	190
N	23	2.5	240	200
NP	24	3.0	260	210
NS	24	3.0	255	209
NPK	24	3.0	249	216
NPKSZn	64	6.0	823	622

Source: Khan *et al.*, (2002).

Appendix 5: Cured leaf weight and grade index of tobacco as affected by different rates of fico-micron and boron

Treatment	Fico-micron	Boron	Green leaf yield ($Kg\ ha^{-1}$)	Grade index (%)
T1	0	0	2368	69.3
T2	0	5	2562	69.7
T3	0	10	2623	68.3
T4	40	0	2554	71.0
T5	40	5	2799	69.3
T6	40	10	2948	66.7
T7	45	0	2608	68.3
T8	45	5	2824	68.3
T9	45	10	2923	62.3
LSD at P= 0.05			282.2	NS

Source: Zafar Hayat Khan, *et al*, (2008).

Appendix 6: Leaf area and green leaf yield of tobacco as affected by different rates of fico-micron and boron

Treatment	Fico-micron	Boron	Leaf area (cm^2)	Green leaf yield ($t\ ha^{-1}$)
T1	0	0	587.0	14. 4
T2	0	5	582.3	15. 7
T3	0	10	631.7	16. 6
T4	40	0	640.7	15. 2
T5	40	5	680.7	17 .4
T6	40	10	690.3	19 .5
T7	45	0	674.7	16 .5
T8	45	5	655.3	17. 7
T9	45	10	625.0	21. 1
LSD at P= 0.05			47.6	215.5

Source: Zafar Hayat Khan, *et al*, (2008)..

Appendix 7: Soil Nutrients critical value for Tanzania

	Very Low	Low	Medium	High	Very high
N (%)	0 - 0.1	0.1- 0.2	0.21– 0.5	>0.5	-
P (mg/kg) or (µg/g)	0.7	-	7-20	>20	
C.E.C (me/100g)	0 - 6.0	6.0 - 12	12.1 - 25	25 – 40	>40
ExtCa (mg/kg)					
Sandy	0 – 0.2	0.2 – 0.5	0.6- 2.5	2.6 – 5	> 5
Clay	0 - 2	2 – 5	5 – 10	10 – 2	> 20
Ext K (mg/kg)					
Sandy	0 – 0.05	0.05 – 0.1	0.11 – 0.4	0.4 – 0.7	> 0.7
Clay	0 – 0.2	0.2 – 0.4	0.4 – 1.2	1.2 – 2	> 2

Source: NSS, Soil Survey Staff (1993).

Appendix 8: Original soil analysis at the start of experiment

Determinant	Values
Sand (%)	39
Silt (%)	28
Clay(%)	33
Texture class	Clay loam
Sub group	Tyic camborthid
Series	Bhalike
pHs	8.20
ECE(dS/M)	1.22
TSS(me/L)	12.2
$Ca^{2+} + Mg^{2+}$+ (me/L)	7.6
Na+(me/L)	3.98
SAL(m mol/L)$^{0.5}$	1.02
CO_3^{2-} (me/L)	-
HCO_3 (me/L)	1.8
Cl^{1-} (mc/L)	1.9
SO_4^{2-} (me/L)	8.5
$CaCO_3$ (%)	7.82
Organic matter (%)	0.76
Olsen P (mg/kg)	5.20
Extractable K(mg/kg)	145

Source: Rehman *et al* (2006).

Appendix 9: Residual effect of P applied to wheat on sorghum fodder

Treatments	P in soil solution (mg/l)	P (mg/kg soil) To be added	P2O5(kg/ha) To be added
T1	Native (0NK)	0	0
T2	Native (+NK)	0	0
T3	0.01	9.20	42.14
T4	0.02	13.15	60.23
T5	0.03	16.20	74.20
T6	0.04	18.79	86.06
T7	0.05	21.08	96.55
T8	0.10	30.12	137.95
T9	0.15	37.12	170.01
T10	0.20	43.05	197.17
T11	0.25	48.29	221.16
T12	0.30	53.04	242.92
T13	0.40	61.51	281.75
T14	0.50	69.00	316.02

Source: Rehman *et al* (2006).

Appendix 10: Residual Olsen- extractable P status of the soil and sorghum fodder yield

Treatments	Residual P after wheat (mg/kg)	Fresh fodder yield (t/ha)	Oven dry fodder Yield (t/ha)
T1	5.20	15.17	5.45
T2	5.10	18.25	6.55
T3	6.05	18.96	6.81
T4	6.60	20.62	7.40
T5	7.4	22.09	7.93
T6	7.95	22.96	8.24
T7	8.65	23.71	8.51
T8	10.10	25.04	8.99
T9	11.80	27.59	9.90
T10	13.15	28.63	10.28
T11	16.85	29.83	10.71
T12	18.55	31.42	11.28
T13	20.50	30.67	11.01
T14	22.40	32.28	11.59
LSD	0.2379	1.260	0.4503

Source: Rehman (2006).

Appendix 11: Phosphorus concentration and uptake by sorghum, Olsen extractable P in soil and P recovery

Treatments	Phosphorus Concentration (%)	Phosphorus uptake (kg/ha)	Phosphorus recovery (%)	Olsen-P extractable after Sorghum (Mg/kg)
T1	0.06	3.27	-	4.70
T2	0.071	4.59	-	4.60
T3	0.071	4.771	1.96	5.00
T4	0.071	5.18	4.49	5.45
T5	0.08	6.34	10.80	6.20
T6	0.09	7.42	15.06	6.75
T7	0.09	7.66	14.56	7.50
T8	0.10	8.99	14.61	7.70
T9	0.10	9.90	14.27	8.25
T10	0.10	10.28	13.22	8.70
T11	0.10	10.71	12.67	9.30
T12	0.11	12.41	14.74	9.75
T13	0.11	12.11	12.23	10.85
T14	0.12	13.91	13.51	10.95
LSD	0.013	0.1300	-	0.2545

Source: Rehman *et al* (2006).

Appendix 12: Percent of phosphorus soil test values in each category in 1975 and 1985 for soils to be planted to important crops in Kentucky

Crop year	Soil test categories				
	VL	L	M	H	VH
	% of samples found in each group				
1975	10.1	7.8	13.5	7.9	72.9
1985	2.2	6.7	13.5	9.0	80.7
1975	37.0	19.1	23.5	7.9	25.8
1985	3.4	22.4	37.0	14.6	34.8
1975	48.2	24.7	22.4	6.7	10.1
1985	3.4	23.5	39.2	16.8	29.2
1975	28.0	15.7	24.7	10.1	33.6
1985	4.5	22.4	25.8	12.3	47.1
1975	65.0	13.5	13.5	4.5	15.7
1985	15.7	37.0	22.4	9.0	28.0

Bray no.1 Very Low << 17 kg/ha, Low = 17 - 34kg/ha, Medium = 34 - 67 kg/ha, High = 67 - 90, Very High >90
Source: Kentucky University (2006).

Appendix 13: Initial P and Build-up Ratio 16 different soils of Kentucky

Initial Soil P(kg/ha)	Buildup Ratio kg P_2O_5/kg Soil P Increase	Initial soil (kg/ha)	Buildup Ratio kg P_2O_5/ kg Soil P Increase
5.6	13.6	72.9	2.3
11.2	8.5	78.5	2.2
16.8	6.4	84.1	2.1
22.4	5.3	89.7	2.0
28.0	4.5	95.3	2.0
33.6	4.0	100.9	1.9
39.2	3.4	106.5	1.8
44.8	3.3	112.1	1.7
50.5	3.0	117.7	1.7
56.1	2.8	123.3	1.6
61.7	2.6	128.9	1.6
67.3	2.4	134.5	1.5

Adapted from Thom & Dollarhide (2002).

Appendix 14: Percent of potassium soil test values in each category in 1975 and 1985 for soils to be planted to important crops in Kentucky

Crop	Crop Year	Soil K test category[1]			
		VL	L	M	H
		% of samples found in each group			
Burley tobacco	1975	10	28	53	19
	1985	7	22	50	33
Corn	1975	28	52	27	6
	1985	13	38	48	12
Soybeans	1975	34	55	20	3
	1985	11	40	49	11
Alfalfa	1975	22	44	37	9
	1985	13	34	47	18
Grass legume forage	1975	34	49	24	6
	1985	18	38	41	15

[1]NH 4 OAC-VL<<84 ha^{-1}, L = 84 - 185 kg ha^{-1}, M = 185 - 280 kg ha^{-1}, H > 280 kg ha^{-1}
Source: Kentucky University (2006)

Appendix 15: Leaf and quality of FCV tobacco as influenced by K levels and their interaction with Mg

	Green leaf Yield (kg ha^{-1})	Cured leaf yield (Kg ha^{-1})	Top Grade Equivalent (Kg ha^{-1})
T_1- Control (No K only NP)	7921	1157	694
T_2- 80kg ha-1 (recommended)	11059	1558	907
T_3- 80kg ha-1 (40 kg through PM+40kg through SOP at 10 DAP	13014	1944	1144
T_5- 120kg K ha^{-1} (40+40+40kg Through SOP at 10.20 and 40 DAP)	12088	1805	1018
T_5- 120kg K ha^{-1} (40kg through PM+40kg through SOP At 10DAP+40kg through SOP At 25 DAP	11805	1720	1013
T_6- T1 + 15 kg MgO ha^{-1}	7955	1162	702
T_7- T2 +15kg MO ha^{-1}	12139	1790	1036
T_8- T3 + 15 kg MgO ha^{-1}	13503	1967	1188
T_9- T4 +15kg MgO ha^{-1}	11805	1722	1029
T_{10}- T5 + 15 MgO ha^{-1}	11831	1725	1090
SEm +	437	49	74
CD at 5%	1300	146	218
CV %	15.4	16.8	13.8

Note: PM – Press mud; SOP – Sulphate of potash:
DAP – Days after planting

Source: Gurumurthy and Vageesh (2007).

Appendix 16: Nitrogen, phosphorus and potassium content in cured leaf of FCV tobacco as influenced by K levels and their interaction with Mg

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	X	L	X	L	X	L
T1- Control (No K only NP)	1.44	1.43	0.23	0.21	2.33	1.9
T2- 80kg K ha-1 (recommended)	1.61	1.54	0.22	0.30	3.17	3.0
T3- 80kg K ha-1 (40kg through PM +40 kg through SOP at 10 DAP)	1.64	1.65	0.25	0.32	3.35	2.7
T5- 120 kg K ha-1 (40 g through PM+40 kg through SOP at 10 DAP + 40 through SOP at 25 DAP	1.78	1.86	0.24	0.34	3.28	2.7
T_6- T_1 + 15 kg MgO ha^{-1}	1.38	1.54	0.25	0.25	2.33	2.0
T_7 - T_2 + 15 kg MgO ha^{-1}	1.78	1.78	0.24	0.26	3.09	2.6
T_8 - T_3 + 15 kg MgO ha^{-1}	1.73	1.67	0.23	0.32	3.24	2.7
T_9 - T_4 + 15 kg MgO ha^{-1}	1.74	1.81	0.23	0.33	2.95	2.6
T_{10} - T_5 + 15 kg MgO ha^{-1}	1.73	1.76	0.20	0.34	2.95	2.7
SEm +	0.06	0.06	0.01	0.04	0.13	0.20
CD at 5%	0.17	0.16	NS	NS	0.39	0.19
CV %	8.1	7.8	10.9	22.3	7.7	13.8

Source: Gurumurthy and Vageesh (2007)

Note: PM – Pres mud; SOP Sulphate of potash; DAP – Days after planting
X = Priming
L = leaf

Appendix 17: Residual effect of B on grain yield of wheat crop

Treatment	Available B (mg kg^{-1})	Grain yield (Mg ha^{-1})
Control	0.45	2.4
1	0.47	2.52
2	0.46	2.57
3	0.47	2.66
4	0.48	2.66
5	0.50	2.71
6	0.49	3.10
7	0.50	3.10
8	0.50	3.05
9	0.51	3.00
P=0.05	LCD = 0.8280	

Source: Shafiq (2008).

Appendix 18: Physical and chemical properties along fertilized and unfertilized plot

Lab .No.	Site Description	PH	N (%)	P (ppm)	K (me/100g)	C (%)	CEC
1	Fertilizer 15 to 20 years	6.0	0.18	7.2	0.93	1.8	34.6
2	" " "	5.2	0.22	23.8	1.13	2.7	26.6
3	" " "	4.8	0.21	15.8	0.53	2.8	32.4
4	" " "	4.9	0.21	24.1	0.50	2.5	30.0
5	" " "	5.5	0.27	36.6	1.08	3.0	28.0
6	" " "	4.7	0.22	82.4	0.71	3.9	23.6
7	" " "	5.5	0.21	65.3	0.66	3.5	28.2
8	" " "	6.1	0.22	40.6	0.89	3.5	27.6
9	From unfertilized adjacent field	5.7	0.22	3.6	0.67	3.6	27.0
10	" " "	6.1	0.18	2.8	0.78	3.3	29.6
S.D		0.53	0.03	26.72	0.24	0.63	3.10
S.E		0.17	0.01	8.06	0.10	0.2	0.98

Source: Kebede and Mikru (2006).

Appendix 19: Some descriptive statistical on indicator parameters of soil samples collected from over 15 years fertilized experimental plots

Lab No.	Site Description	DTPA – Soluble micronutrients (ppm)			
		Fe	Mn	Zn	Cu
1	Fertilizer 15 to 20 years	32.8	148.2	2.8	3.2
2	" " "	58.1	124.5	3.3	3.7
3	" " "	46.5	131.5	2.3	3.7
4	" " "	49.8	155.9	2.7	3.1
5	" " "	52.8	101.8	2.9	3.1
6	" " "	63.2	219.1	5.5	4.5
7	" " "	61.9	131.9	3.0	2.7
8	" " "	68.4	172.6	3.3	4.2
9	From unfertilized adjacent fields	32.4	157.2	1.9	3.2
10	" " "	48.9	109.1	2.1	3.3
S.D		3.8	10.8	0.34	0.74
S.E		12.1	34.1	1.1	0.6

Source: Kebede and Mikru (*2006*).

Appendix 20: Pre-cropping soil and manure chemical analysis

	Soil sample	Organic manure
pH (H2O)	6.1	8.2%
Organic manure	2.9%	30.5%
Organic carbon	1.7%	17.8%
Total –N	0.2%	1.8%
Available - P	1.7 ppm	0.5%
Exchangeable – K	0.3 cmolkg^{-1}	0.12%
Exchangeable - Ca	3.7 cmolkg^{-1}	0.7%
Exchangeable – Na	0.5 cmolkg^{-1}	0.7%
Exchangeable – Mg	0.5 cmolkg^{-1}	0.01%
Exchangeable – Acidity	0.1 cmolkg^{-1}	
ECEC	5.1 cmolkg^{-1}	
Sand	742 g kg^{-1}	
Silt	131 g kg^{-1}	
Clay	145 g kg^{-1}	

Source: Makinde and Ayoola (2010).

Appendix 21: Estimated quantity of NPK applied

	Nitrogen	Phosphorus	Potassium
	(kg ha^{-1})		
Organic fertilizer	178.0	46.0	17.0
Org + inorganic fertilizers	123.5	29.5	8.5
Inorganic fertilizer	69.0	13.0	0.0

Source: Makinde and Ayoola (2010).

Appendix 22: Summary of sampled farmers' fields information

No	District	Farmer	Soil type	Crop rotation	Years under cultivation	Crop rotation
1	Uyui	James Ndindwagogo	Kikungu	Maize	9	Tobacco, maize
2	Uyui	Hamis Kashindye	Mbuga	Maize	8	Tobacco, maize
3	Uyui	Mrisho Hassani	Isenga	Tobacco	10	Tobacco, maize
4	Uyui	Noah George	Kikungu	Tobacco	9	Tobacco, maize
5	Uyui	Joseph Shekipindi	Isenga	Tobacco	8	Tobacco, maize
6	Tabora	Selemani Kavelele	Isenga	Tobacco	10	Tobacco, maize
7	Tabora	Hamisi Mwinyi	Kikungu	Tobacco	9	Tobacco, maize
8	Tabora	Florence Mduma	Isenga	tobacco	9	Tobacco, maize beans
9	Tabora	Mrisho Ally	Kikungu	Tobacco	8	Tobacco, maize
10	Tabora	Musa Mohamed	Mbuga	Maize	10	Tobacco, maize and beans
11	Sikonge	Rashid Magope	Isenga	Tobacco	10	Tobacco, maize and beans
12	Sikonge	Yasini Katangala	Isenga	Tobacco	9	Tobacco, maize and beans
13	Sikonge	Mwigulu Thomas	Kikungu	Tobacco	8	Tobacco, maize and sweet potatoes
14	Sikonge	John Thomas	KIkungu	Tobacco	9	Tobacco, maize and beans
16	Sikonge	Yasini Saidi	Mbuga	Tobacco	8	Tobacco, maize
16	Urambo	Kephas Kasendeka	Kikungu	Maize	8	Tobacco, maize
17	Urambo	Omari Yeye	Isenga	Tobacco	9	Tobacco, maize, ground nut
18	Urambo	Zakaria Kishau	Kikungu	Tobacco	6	Tobacco, maize
19	Urambo	Hamisi Utwa	Mbuga	Maize	8	Tobacco, maize
20	Urambo	Martin Myango	Isenga	Tobacco	8	Maize, beans

Appendix 23: Pot experiment treatment break down

TN	Treatment	Treatment breakdown
1	Control (No fresh fertilizer)	
2	Residual plus recommended N 80.5 kg N/ha	i) Amount per pot= 80.5 kg x 1 000 000 / 2 000 000 kg = 80.5mg / 2 kg = 40.25 mg N/kg
	Recommended NPK plus B (10:18:24, +0.1)	
3	i)Amount of N.....	N in 30g NPK = 30g x 10 = 3gN/pot = 3000 mgN/10kg soil / 100 = 300mg/kg **N applied was 300mg Kg^{-1} soil**
	ii)Amount of P applied.....	P_2O_5 is 18% m conversion factor for P is 0.44 18 x 0.44 x 30 / 100 = 2.376g P/10 kg = 0.2376 g / kg = 238mg P/ kg soil **Amount of P applied was 238mg P /kg soil**
	iii) Amount K to be applied	K_2O = 24% , conversion factor to K is 0.83 24 x 0.83 x 30g / 100 = 5.976gK/10Kg soil = 0.5976g K/Kg soil = 597.6mg/Kg soil **Amount of K applied was 598mg Kg^{-1} soil**
	iv) Amount of B	B is 0.1% 0.1 x 30g / 100 = 0.003 x 1,000mg/Kg soil = 3mg B/Kg **Amount of B applied was 3mg Kg^{-1} soil**
4	NPK Plus B (10:18:24 + 0.1) 45g plants in 10 Kg soil	
	i)Amount of N.....	N = 10 x 45g / 100 = 4.5gN 10 Kg^{-1} soil .. 0.45gN/Kg = 0.45gN x 1000 = 450mgN/ Kg^{-1} soil **Amount of N applied was 450mg Kg^{-1} soil**
	ii)Amount of P applied	P. P_2O_5 = 18 %, conversion factor to P is 0.44 P = 18 x 0.44 / 100 x 45g = 3.564g/10kg soil = 0.3564g P/Kg soil **Amount of P applied was 356.4 mg Kg^{-1} soil**

	iii) Amount K to be applied	**K** $\frac{24 \times 0.83}{100} \times 45g$ 8.964g/10Kg soil = 0.8964gK/kg soil = 0.8964gK/kg soil x1000 = **896.4mg kg^{-1} soil** **Amount of K applied was 896.4mg kg^{-1} soil**
	iv) Amount of B	**B.** $\frac{0.1}{100} \times 45g$ = 0.045g/10kg soil = 0.0045g/kg soil = 0.0045gB x1000 kg^{-1} soil = 4.5mgB kg^{-1} soil **Amount of B applied was 4.5mg kg^{-1} soil**
5	NPK Plus B (10:18:24 to 0.1), 45g plant $^{-1}$	
	i)Amount of N.....	N = $\frac{10}{100} \times 45g$ = 4.5gN 10 Kg^{-1} soil = 0.45gN/Kg = 0.45gN x 1000 = 450mgN/ Kg^{-1} soil **Amount of N applied was 450mg Kg^{-1} soil**
	ii)Amount of P applied.....	**P.** P_2O_5 = 18 %, conversion factor to P is 0.44 P = $\frac{18 \times 0.44}{100} \times 45g$ = 3.564g/10kg soil = 0.3564g P/Kg soil **Amount of P applied was 356.4 mg P Kg^{-1} soil**
	iii) Amount K to be applied	conversion factor to K is 0.83 $\frac{24 \times 0.83}{100} \times 45g$ = 8.964g/10Kg soil = 0.8964gK/kg soil = 0.8964gK/kg soil x1000 = 896.4mg kg^{-1} soil **Amount of K applied was 896.4mg kg^{-1} soil**

	iv) Amount of B	B. $\frac{0.1}{100} \times 45g$ = 0.045g/10kg soil = 0.0045g/kg soil = 0.0045gB x1000 kg^{-1} soil **= 4.5mgB kg^{-1} soil**
	v) Mg (50mgKg^{-1})	
	vi) Zn (10mg Kg^{-1})	
6	NPK plus B (10:18:24, to 0.1), 45g $plant^{-1}$ 5g CAN,	
	i) N from NPK+B (10:18:24, to 0.1)	N = $\frac{10}{100} \times 45g$ = 4.5gN 10 Kg^{-1} soil = 0.45gN/Kg = 0.45gN x 1000 **N from NPK+B was 450mgN kg^{-1} soil**
	ii) N: from 5g CAN 27%	$\frac{27}{100} \times 5g$ = 1.35g/10kg soil = 0.135g kg^{-1} soil = 0.135g/ kg^{-1} soil x 1000 = 135mg kg^{-1} soil **Total N = (450mg + 135 mg) N kg^{-1} soil** **= 585 mg kg^{-1} soil**
	iii)	P: From (V) 356.4mg P kg^{-1} soil K: From (V) 896.4mg K kg^{-1} soil B: From (V) = 0.45mgB kg^{-1} soil
	v) Mg (50 mg kg^{-1})	
	iv) Zn (10 mg kg^{-1}):	

Appendix 24: Field experiment, treatment breakdown

Treatment	Treatment breakdown
Treatment (ii)	1 Re commended N from urea 126.26 kgha^{-1}. 2 Half recommended K 53.12 kgha^{-1} 3 P maintenance level 10kg/ha $^{-1}$ 4 Zn 5kgha^{-1} 5 Cu 2.5kg ha^{-1}
10 kg P ha^{-1} from of NPK 10:18:24; 0.01	100Kg NPK = 18 x 0.44kgP X = 10kgP = $\frac{100\text{kg NPK x 10kg P}}{18\text{kg x 0.44P}}$ = $\frac{1000\text{KgNPK}}{18 \times 0.44}$ = 126.26KgNPK The amount of NPK 10:18:24 which will supply P ≡ 10Kg/ha was **126.26kg**
Amount of K_2O	126.26kg of N.P.K. 10:18:24 has: K_2O = 24% N = 10% (i) Amount of K_2O $\frac{24}{100}$ x 126.26 = 30.3Kg K_2O K_2O was changed to K by multiplying a factor and the value of K_2O. 30.3 x 0.83 = 25.15kgK 126.26 kg of NPK 10:18:24 gave **25.15kg K** (ii) Amount of N $\frac{10}{100}$ x 126.26 = 12.63KgN The difference between the recommended rate and the amount came out of NPK 10:18:24 for: N and K: N: required 80.5kgN – 12.63kgN = 68.87kgN(deficit) K: required was half recommended minus K supplied by NPK 10:18:24 $\frac{128\ K_2O \times 0.83}{2}$ = 53.12 kg K (half recommended) 53.12 kg K – 25.15 kg K = 27.97kg K(deficit) 27.97 kg ha^{-1} was added from $KHSO_4$

Remaining N: came from Urea (N is 46%)

100Kg Urea = 46kgN

X = 67.87 kg N

$$X = \frac{100kgUrea \times 67.87kgN}{46kgN}$$

$$X = \frac{100kg \times 67.87\ Urea}{46}$$

$X = 147.543kg\ Urea\ ha^{-1}$

$$\frac{10,000m2}{1.0m \times 0.6m} = 16,666.66\ plant\ ha^{-1}$$

$$\frac{147543.5g}{16,666.66\ plants} = 8.85g\ plant$$

Amount of urea per plant was 8.85g

K: required was 27.97 Kg

$KHSO_4$ was the source of K. Molecular weight of $KHSO_4$ = 136.16g. Atomic weight of K = 39g

The percentage of K in $KHSO_4$ was

$$\frac{39 \times 100}{136.16} = 28.64\%$$

100kg $KHSO_4$ = 28.64kgK

X = 27.97kgK

$$X = \frac{100kg\ KHSO_4 \times 27.97kgK}{28.64kg\ K}$$

100kg $KHSO_4$ = 28.64kgK

X = 27.97kgK

$$X = \frac{100kg\ KHSO_4 \times 27.97kgK}{28.64kg\ K}$$

$$X = \frac{2797kg\ KHSO_4}{28.64}$$

= 97.6606 kg $KHSO_4$

Amount of $KHSO_4$ to be added to the plant

$$\frac{97.6606\ kg \times 1000}{16,666.66plants}$$

= **5.86g $KHSO_4$ plant^{-1}**

The treatment (ii) summary;

Urea	= 8.85g plant^{-1}
NPK (10:18:24)	= 7.56g plant^{-1}
$KHSO_4$	= 5.86g plant^{-1}

Amount of Zn	Zn added was 5Kgha $^{-1}$ from the following ZnO 5Kg Zn $^{-1}$ was the same as 5000g Zn $^{-1}$. Plant population was 16,666.66 Amount of Zn plant^{-1} $\frac{5000g}{16,666.66}$ plant = 0.3g Zn plant $^{-1}$ Zn comes from ZnO Molecular weight of ZnO = 81.4g, Atomic weight of Zn = 64.5g Percentage of Zn in ZnO is: $\frac{65.4 \times 100}{81.4}$ = 80.34% Then: 100 ZnO = 80.34gZn X = 0.3gZn $X = \frac{100g\ ZnO \times 0.3gZn}{80.34gZn} = \frac{100 \times 0.3gZnO}{80.34}$ = 0.37gZnO **Amount ZnO plant^{-1} was 0.37g**
Amount of Cu	Cu 2.5kg ha^{-1} 2.5kg Cu ha^{-1} was the same as 2500g Cu ha^{-1}
Amount of Cu	To find amount of Cu plant^{-1} $\frac{2500g}{16,666.66}$ = 0.15g Cu plant^{-1} But Cu came from $CuSO_4.5H_2O$ The molecular weight of $CuSO_4.5H_2O$ is 249.58 Atomic weight of Cu is 63.55g Percentage of Cu in $CuSO_4.5H_2O$ is $\frac{63.55g \times 100}{249.68g}$ = 25.5% If 100g $CuSO_4.5H_2O$ gives 25.5g Cu How much of $CuSO_4.5H_2O$ will give 0.15g Cu? 100g$CuSO_4.5H_2O$ = 25.5gCu X = 0.15gCu $X = \frac{100g\ CuSO_4.5H_2O \times 0.15gCu}{25.5g\ Cu}$

	$= \frac{100g \times 0.15\ CuSO_4.5H_2O}{25.5}$ $= \frac{15g\ CuSO_4.5H_2O}{25.5}$ $= 0.588g\ CuSO_4.5H_2O$ The amount of $CuSO_4.5H_2O$ which gave 0.15gCu $plant^{-1}$ is 0.588g
Treatment (iv)	
	Treatment (iv) Application was 50kgMg ha^{-1} = 5000g Mg ha^{-1} Amount per plant = Quantity in / Plant population of ha = 50,000gMg / 16,666.66plants = 3gMg $plant^{-1}$ Mg came from $MgSO_4.7H_2O$.Molecular weight of $MgSO_4.7H_2O$ is 246.47g. Atomic weight of Mg is 24.3g. The percentage of Mg in $MgSO_4.7H_2O$ $\frac{24.3g}{246.47g} \times 100 = 9.86g\ Mg$ 100g $MgSO_4.7H_2O$ = 9.86g Mg X = 3gMg $X = \frac{100g\ MgSO_4.7H_2O \times 3gMg}{9.86gMg}$ $X = \frac{100 \times 3g\ MgSO_4.7H_2O}{9.86}$ X = 30.425g $MgSO_4.7H_2O$ **Amount of $MgSO_4.7H_2O$ $plant^{-1}$** **Zn application was 5kg/ha** 5kgZn = 5000gZn Amount of Zn applied per ha. = Quantity in grams / Plant population of a ha $= \frac{5000g}{16,666.66} = 0.3g\ Zn\ plant^{-1}$ Zn came from ZnO

	Molecular weight of ZnO = 81.4g Atomic weight of Zn = 65.4g The percentage of Zn in ZnO is $\frac{65.4 \times 100}{81.4} = 80.34\%$ If 100gZnO = 80.34gZn X = 0.3gZn $X = \frac{100gZnO \times 0.3gZn}{80.83gZn}$ $X = \frac{30gZnO}{80.34}$ **0.37gZnO was applied per plant** CAN Amount of CAN 27% was5g plant $^{-1}$ $= \frac{27}{100} \times 5g = 1.35gN$ plant $^{-1}$
Treatment (v)	Mg as treatment (iii) Zn application Zn (10mgKg^{-1}) $\frac{10KgZn}{1,000,000} = 1Kg$ soil X = 2,000,000kg soil
	$X = \frac{10KgZn \times 2,000,000kg\ soil}{1,000,000 \times 1kg\ soil}$ $= \frac{10kg\ Zn \times 2,000,000}{1,000,000}$ = 20KgZn 1 ha = 10,000m^2 1 ha = 2,000,000 kg soil = 20kg Zn Then 20kgZn = 10,000m^2 X = 30 m^2 $X = \frac{2kgZn \times 30\ m^2}{10,000\ m^2}$ $= \frac{600kgZn}{10,000}$ X = 0.06kgZn per 30m^2

	Amount of Zn per plant 0.06kgZn x 1000 = 60g 60g = 1.2gZn plant $^{-1}$ 50plants Zn is provided by ZnO. Molecular weight of ZnO is 81.4g. Atomic weight of Zn is 65.4g .Percentage of Zn in ZnO is $\frac{65.4}{81.4} \times 100 = 80.34\%$ If 100gZnO = 80.34gZn X = 1.2gZn X = $\frac{100g\ ZnO \times 1.2gZn}{80.34gZn}$ $x = \frac{120ZnO}{80.34}$ x = 1.494gZnO Amount of ZnO per plant is 1.494g NPK is 45g plant $^{-1}$ N = $\frac{10}{100} \times 45g$ = 4.5gN P = $\frac{(18 \times 0.44)}{100} \times 45g$ = 3.564g plants^{-1} K = $\frac{(24 \times 0.83)}{100} \times 45g$ = 8.964g plants^{-1}
Treatment (vi)	Mg application was as treatment (iii & v) Amount per plant of $MgSO_4.7H_2O$ was 60.85g Zn application as treatment (v). NPK: 10:18:24+ 0.1B 60g plant -1 N = $\frac{10}{100} \times 60g$ = 6gN plant^{-1} P = $\frac{(18 \times 0.44)}{100} \times 60g$ = = 4.75gP plant^{-1} K = $\frac{24 \times 0.83 \times 60g}{100}$ = 11.952g K plant^{-1}

Appendix 25: Pot experiment plant survival per treatment;

Treatment	Réplication			Total	(%)
	I	II	III		
T1	10	10	10	30	100
T2	10	9	9	28	93
T3	8	9	6	23	77
T4	4	7	6	17	57
T5	6	4	2	12	40
T6	2	1	2	5	17

Appendix 26: Field experiment, plant survival in sampled plots

Treatment	Réplication			Total	(%)
	I	II	III		
T1	18	18	18	54	93
T2	18	18	17	53	98
T3	16	18	18	52	96
T4	17	17	17	51	94
T5	18	18	18	54	93
T6	18	18	16	52	96

Appendix 27: Water management in the pots

S/n	Soil sources	Soil type	Field capacity (litres)	90% field capacity (litres)
		Kikungu	1.6	1.4
1	Urambo	Isenga	1.0	1.0
		Mbuga	1.5	1.3
		Kikungu	1.3	1.2
2	Tabora	Isenga	1.3	1.2
		Mbuga	1.4	1.3
		Kikungu	1.2	1.1
3	Uyui	Isenga	1.2	1.0
	Sikonge	Kikungu	1.2	1.1
4		Isenga	1.1	1.0

Appendix 28: Indicative price for flue cured tobacco, season 2009/2010

S/n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Grade	P30	P3L	P40	P4L	P50	P5L	X30	X3L	X40	X4L	X50	X5L	XOV	XLV	XOJ	XLJ	XOK
Usd	2.241	2.133	1.993	1.968	1.650	1.500	2.421	2.286	2.211	2.111	1.869	1.709	1.360	1.251	0.894	0.842	0.28
S/n	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Grade	XLK	XN1O	XN1L	XN2O	XN2L	XNK	C1O	C1L	C2O	C2L	C3O	C3L	C4O	C4L	L1OF	L2OF	L3OF
Usd	0.250	1.563	1.466	1.323	1.206	0.182	2.700	2.680	2.661	25	2.446	2.354	2.230	2.220	3.022	2.962	2.912
S/n	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
Grade	L4OF	L5OF	L1O	L1L	L2O	L2L	L3O	L3L	L3O	L4L	L5O	L5L	LR	LOV	LLV	LOJ	LLJ
Usd	2.811	2.661	2.945	2.880	2.866	2.821	2.761	2.620	2.515	2.386	2.070	1.931	2.079	1.660	1.580	1.043	0.950
S/n	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
Grade	LOK	LLK	N1O	N1L	N2O	N2L	NK	LOKD	LLKD	LOG	LLG	B1O	B1L	S1O	S1L	S2O	S2L
Usd	0.325	0.292	1.673	1.586	1.500	1.375	0.218	0.270	0.247	0.155	0.148	0.448	0.403	0.350	0.330	0.300	0.230

Source: Tanzania Tobacco Board (TTB) (2010)

Appendix 29: Reference of sufficiency ranges for flue cured tobacco for Southern region of the United State of America

Macronutrients (%)							
Growth stage	Tissue	N	P	K	Ca	Mg	S
Seedling	MRML	4.0 - 6.0	0.2 - 0.5	3.0– 4.0	0.6- 1.5	0.2-0.6	0.15-0.6
Early growth	MRML	4.0 - 5.0	0.2 - 0.5	2.5 - 3.5	0.75-1.5	0.2-0.6	0.15-0.6
Flowering	MRML	3.5 - 4.5	0.2 - 0.5	2.5 - 3.5	0.75-1.5	0.2-0.6	0.15-0.6
Maturity	MRML	2.25 – 3.0	0.17-0.5	1.6 -3.0	0.75-1.5	0.2-0.6	0.15-0.6
Harvest	Upper leaf	2.0 – 2.25	0.14-0.3	1.5– 2.5	0.75-1.5	0.2-0.6	0.15-0.4
Harvest	Middle leaf	1.6 – 2.0	0.13- 0.3	1.5– 2.5	1.0-2.0	0.2-0.6	0.15-0.4
Harvest	Lower leaf	1.3 - 1.75	0.12- 0.3	1.3-2.5	1.0-2.5	0.18-0.75	0.15-0.4

Micronutrients (ppm)						
Growth stage	Tissue	Fe	Mn	Zn	Cu	B
Seedling	MRML	50-300	20-250	20-60	5-10	18-75
Early growth	MRML	50-300	20-250	20-60	5-10	18-75
Flowering	MRML	50-300	20-250	20-60	5-10	18-75
Maturity	MRML	50-300	20-250	20-60	5-10	18-75
Harvest	Upper leaf	40-200	20-350	18-60	5-10	18-30
Harvest	Middle leaf	40-200	20-350	18-60	4-10	18-30
Harvest	Lower leaf	40-200	18-350	18-60	3-10	15-30

Source: Southern Cooperative Series Bulletin (SCSB)
MRML: Most recent mature leaf (2009)

SPE
SB278