SOIL NITRATE TEST TO ASSESS THE NITROGEN FERTILIZER NEED FOR TROPICAL SOILS: A CASE OF MOROGORO DISTRICT

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A DISSERTATION SUBMITED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN SOIL SCIENCE AND LAND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

Soil nitrate test of Soil Doc protocol has potential to identify optimum N fertilizer requirements for optimizing economic return, while reducing environmental impact. The purpose of this study was to develop N fertilizer requirements for maize production based on the soil nitrate test for the tropical soils in Morogoro District, Tanzania using soil Doc Protocol. Composite soil samples were collected pre-planting (PPNT) and pre-topdressing (PTNT) of N fertilizers to determine soil NO_3-N. The PPNT soils samples were also used for determining soil physical and chemical properties. The experiment was conducted in the two villages, the treatments consisted of two soil NO_3^- level (medium and high) , three nitrogen fertilizer rate: 80 kg N ha^{-1}, 40 kg N ha^{-1}, and control (0 kg N ha^{-1} arranged in a randomized complete block design (RCBD) with factorial treatment structure. Initial soil properties were medium salinity pH and extremely low organic carbon and available P for all soils in both villages. The results revealed that maize growth parameters (fresh weight, dry weight, grain yield and total N) increased significantly ($p<0.001$) with increase in nitrogen fertilizer rate. The 80 kg N ha^{-1} rate had significantly highest response. Also there was no significant interaction between soil NO_3 level and fertilizer rate. The results at two sampling times were statistically not significant different. The soil nitrate levels increased over time from PPNT sampling to PTNT time of sampling but did not affect the response to applied N fertilizer. Therefore it is worth to apply N fertilizer to these soils for optimum maize production. It was recommended that more studies should be conducted in different tropical soils, climates and location to determine how soil NO_3-N at different stages of maize growth can guide N fertilization.

DECLARATION

I GLADNESS MARTIN BRUSH, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

I dedicate this work to my beloved daughter Melissa Mussa Kitivo who gives me an extra strength to work much hard. It is also dedicated to my lovely mother Busara Elinazi Mnzava whom her humble prayers keep me going.

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LIST OF ABBREVIATIONS AND SYMBOLS

<	Less than
>	Greater than
Active C	Active carbon
ANOVA	Analysis of variance
C	Carbon
C/N	Carbon to Nitrogen ratio
cm	Centimetre
CV	Coefficient of variation
et al	And others
FAO	Food and Agriculture Organization of the United Nations
g	Gram
K^+	Potassium
$KMNO_4$	Pottasium Permanganate solution
LSD	Least Significance Difference
masl	Metres above sea level
mg kg^{-1}	Milligrammes per kilogram
mm	Millimetre
N	Nitrogen
NH_4^+	Ammonium ion
NO_3^-	Nitrate ion
^{O}C	Degree Celsius
P	Phosphorus
P_2O_5	Phosphorus pentoxide

pH	Negative logarithm of hydrogen ion concentration
PPNT	Pre Planting Nitrate Test
PTNT	Pre Topdressing Nitrate Test
S	Sulphur
SO_4^{2-}	Sulphate ion
SOM	Soil organic matter
SUA	Sokoine University of Agriculture
t ha^{-1}	Tonnes per hectare
USA	United States of America

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Nitrogen occupies a unique position among essential elements because most agricultural crops require proportionally more N than other nutrients to achieve maximum yield. So N is considered the most important growth-limiting factor in crops in which maize is included (Zebarth *et al.*, 2009). This has made the management of N to be of great importance for both economic and environmental reasons. Optimizing N management will improve agronomic performance and increase economic returns, as well as reduce N losses from the environment. One approach to reduce environmental pollution and improve profitability is to monitor N fertilizer applications to meet the N crop requirement (Sharifi *et al.*, 2007; Zebarth and Rosen, 2007) by synchronizing the application of plant-available N with maize N uptake in space and time (Ma *et al.*, 1999). However, this has been difficult to achieve due to substantial variation in both maize N demand and the availability of N in the soil within season and within and between fields (Zebarth *et al.*, 2009).

Soil nitrate testing is one way of evaluating the available nitrogen (N) status of the soil. Some studies in the US show that the use of soil nitrate test ensure the best management of N in soil. In the Northeast United States soil nitrate test has been used to accurately predict maize N fertilizer need (Magdoff *et al.*, 1984). In Minnesota the soil nitrate test was used to measure the residual or carryover NO_3^{-}N, which was used to adjust fertilizer recommendations for maize, small grains, edible beans, sugar beets, canola and sunflower (Rehm *et al.*, (1999).

Some concerns have been accounted based on soil NO_3 tests. Soil NO_3 tests may result in N fertilizer recommendation that under predicts crop N need because of precipitation, soil permeability, and climatic conditions that changes N availability after the soil sample is taken (Magdoff, 1991). The tests have shown varying results when performed pre-plant, pre-side-dress, and post-harvest because of its dynamic nature in the soil (Williams, 2005). The amount of residual NO_3-N in soil is influenced by moisture content of the soil, water holding capacity, soil texture and the rooting pattern of the previous crop. These factors make soil nitrate test to be variable over time and space (Rehm *et al.*, 1999). The accuracy of NO_3 test can be achieved by timing the great maize N demand and avoiding measuring NO_3 that maybe lost due to denitrification or leaching. It is impossible to achieve high maize yields if nitrate-N in the root zone is too low. The suitability of soil nitrate-N test for optimum N management is important for maize production in small scale farming systems in the tropics and hence for optimum maize yield and N management; the sampling for NO_3-N test has to be done at an appropriate time. So the adoption of simplified and yet quantitative modern technology of soil analysis (Soil Doc Protocol) is needed in African countries. In many African countries accessibility of conventional soil testing in Soil laboratory is low among small scale farmers and time consuming, which makes impossible to utilize NO_3-N for N fertilization within a season.

1.2 Problem Statement and Justification

Nitrogen is the most limiting element leading to low maize production. As result, N fertilizer use is essential for profitable maize yield. However, N fertilization is also a major production cost and can contribute to environmental degradation. Thus, accurate knowledge on if N fertilizer is needed and how much N fertilizer to apply will help to maximize yield and avoid wastage of resources. Two soil NO_3 tests have been developed that differ in the time and depth of sampling. With the pre plant NO_3 test (PPNT), profile samples are collected early in the particular season to a depth of 60 or 90 cm, to account for residual N from previous season (Roth and Fox 1990; Schmitt and Randal 1994). The pre top-dress NO_3 test (PTNT), soil sampling is done to a depth of 30 cm during the growing season, so that the mineralized N can be taken into account and supplemented, if necessary, by topdressing (Magdoff *et al*. 1984; Fox *et al*. 1989, Blackmer *et al*. 1989, Meisinger *et al*. 1992, Bundy and Andraski. 1993).

This study investigates the appropriate timing of soil nitrate testing for maize production in the tropics in order to increase yield by accurate N fertilizer recommendation. This investigation is justified by the importance of the Morogoro region in national maize production and by the substantial use of N fertilizer in the region. In addition, it is also justified due to the low yield of maize in the tropics which is about 1.2 t ha^{-1} (Mekuria, 2009; Kimaro *et al.*, 2009; Masawe and Amuri, 2012) which is far below the world's average yield of about 5.2 t ha^{-1} (FAO, 2011) and the national average yield of 4.5 t ha^{-1} (Masawe and Amuri, 2012).

Due to soil variability in physical, chemical, and biological properties and time constraints, the laboratory measurements of soil NO_3 is often impractical for producers (Bast, 2009). This is because farms are diverse and small, and farmers have low income to afford the laboratory analysis cost. Quick, in-season estimates of

N availability using soil NO_3-N tests may be more useful for producers to adjust N fertilizer recommendation because they reflect the current season's growing conditions and can be done more timely. The soil nitrate test by soil doc protocol has potential to save the economy for farmers as well as benefiting the environment (Weil and Gatere, 2014). Also the analysis by soil doc protocol can be done right at the field hence it can be easily accessed by farmers and extension agents, to diagnose the nutrient status of the soils they manage, and rapid feedback on soil characteristics.

1.3 Objectives

1.3.1 Overall objective

The overall objective of this study was to develop N fertilizer requirements for maize production based on the soil nitrate test for the tropical soils.

1.3.2 Specific objectives

i. To monitor changes in soil nitrate level over the growing season.

ii. To establish the best sampling time for soil nitrate test for N fertilizer requirement

iii. To determine the response of maize to applied N at different soil NO_3^- levels

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Nitrate Dynamics in Soil

Nitrogen exists in the atmosphere as dinitrogen gas (N_2), oxides (N_2O, NO, and NO_2), and in the reduced form (NH_3). These N forms also exist in soil as dissolved gases. There are several possible non-fertilizer additions to the plant available (NH_4^+ and NO_3^-) soil N pool. The biological conversion of atmospheric N_2 to NH_4^+ or NO_3^- can supply N to leguminous plants through a symbiotic relationship with N-fixing microorganisms. Lightning can also convert atmospheric N_2 into plant available forms (Bast, 2009). In the living tissues N is converted from one chemical form to another through assimilation process and returned into the soil in form of plant litter-fall and root turnover through the process of N mineralization and microbial immobilization.

Nitrogen is lost from the soil through (denitrification, NO_3 leaching, and NH_3 volatilization (Hart *et al*. (1994). Denitrification occurs when fields are waterlogged. Under anaerobic conditions, NO_3 serves as the electron acceptor for microorganisms and is reduced to gaseous N_2 forms. Ammonia volatilization is another process in which N is lost in a gaseous form. Volatilization occurs primarily when urea-based fertilizers or animal manures are not incorporated into the soil (Bast, 2009). The entrance, removal and/or lost and subsequent reentry of N between the soil and atmosphere complete the global N cycle.

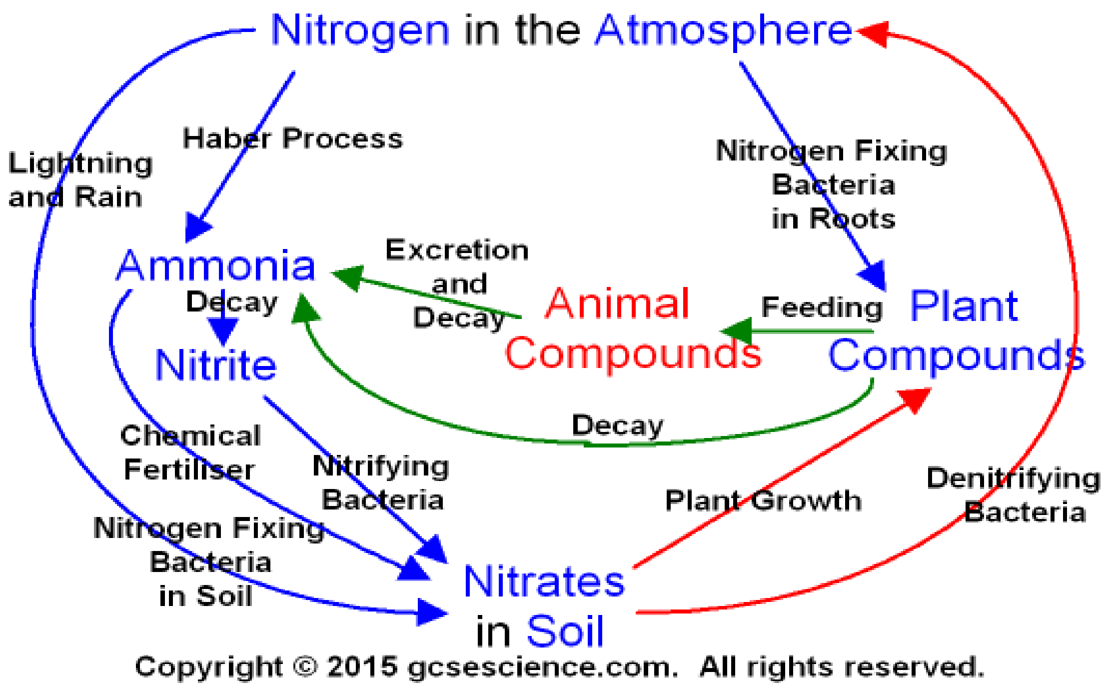

Figure 1: Nitrogen cycle.

2.2 Influence of Soil Properties on Soil NO_3-N

The dynamics of N in the soil is due to the rate of N cycle process which is directly influenced by moisture, aeration and temperature and indirectly by soil properties (biological, physical and chemical). For example, in loamy soils mineralization of N from an organic form tends to be more rapid than clay soils because of better aeration (Williams, 2005). Soil properties have been used to understand N in the soil as they determine the availability of N to the crop. Areas of the field which are susceptible to a high rate of N mineralization may need less N fertilizer. High clay soils may be susceptible to denitrification and soils with a high sand content have high leaching potential. High clay or sand content soils may need more N fertilizer than soils with a loamy texture.

Soil organic matter, texture and soil series may act as surrogates for measuring N mineralization and denitrification and aid in developing an in-season variable-rate fertilizer recommendation (Schmidt *et al*., (2002); Delin and Linden, 2000), Blackmer and White, 1996). Nitrogen is made available for plant uptake from organic matter through mineralization. A study by Delin and Linden, 2000 established a relationship between the amount of soil organic matter and N mineralization potential. Soil organic N could be used to estimate N mineralization rates of the soil and be used to modify variable-rate application of N fertilizer (Williams, 2005).

Soil texture has a marked effect on the availability of the NO_3-N in the soil. For example the percent clay, influences the rate of denitrification and N mineralization (Delin and Linden, 2000). high rates of denitrification and slow N mineralization rates is associated with fine textured soils whereas loamy soils have slower denitrification rates and faster N mineralization rates (Delin and Linden, 2000).These relationships between soil texture and N mineralization and denitrification should aid in developing an in-season variable-rate N fertilizer recommendation (Williams, 2005).

Different soil series have different rates of mineralization, denitrification, immobilization, and volatilization and they interact differently with applied N fertilizer. Research has found N treatment plots that receive the same amount of N can have different N responses. These N responses may be related to soil characteristics captured in soil survey maps. Therefore, soil surveys may be helpful in developing a preseason, at-plant, or in-season variable-rate N fertilizer strategy

(Blackmer and White. 1996). Soil organic matter and soil texture are properties that might aid in predicting mineralization and denitrification of N in the soil, because they indirectly measure soil properties (soil moisture, aeration, and temperature) that control rates of microbial processes. Soil survey maps and bare soil images (Blackmer and White, 1996) might also be used to identify areas that have similar N mineralization and denitrification rates.

2.3 Nitrogen Fertilizer Requirement for Maize Production

Nitrogen is important for optimum maize production as it is for other essential nutrients. The main nutrients applied routinely as fertilizers to agricultural soils are N, P and K (Hynes and Naidu, 1998). Worldwide, nitrogen fertilizers are more heavily used than other fertilizers. This is due to the fact that in most of the agricultural systems, nutrients supply, especially nitrogen, is below the minimum requirement for crops to reach maximum yield (Galvis-spinola *et al.*, 1998).

Maize crop needs different quantity of N at different growth stages because each stage of development is critical for proper maize production. A healthy maize crop needs significant amounts of N between 25 to 29 days after emergency (V5) and reproductive stages to achieve maximum grain yields (Schroeder *et al.*, 2000). Contrary, Fernandes (2005) reported that the maize crop needs little N at early vegetative stages at 25 to 29 days after emergence (V5). Similar to Schroeder *et al.*, (2000), Fernandes (2005) reported that high N is needed during eighth leaf, 31 to 38 days after emergence (V8) to tasseling (VT). This confirms that the greatest amount of N is taken up by the plant between V9-VT (tasseling) growth stages. These findings imply that the N fertilizer has to be applied in a split method. A split application of N fertilizer involves applying a small portion of pre plant N fertilizer combined with a large portion of N at topdressing after the crop has been established (Bast, 2009). Nitrogen application in splits has been proved to be a best practice because it reduce various losses and resulted to higher dry matter accumulation and plant height in maize as compared to sole application (Mitiku, 2014). A study by Rizwan *et al.,* (2003) also supports that Nitrogen application in splits resulted to maximum plant height and grain yield of maize as compared to sole application.

However a reliable method is needed to estimate nitrogen (N) fertilizer requirements for maize production. Optimal applications of N fertilizer are desirable for both economic and environmental reasons. If N is applied insufficiently, crop yields will be reduced, whereas excessive application, apart from causing unnecessary cost to the grower, will also depress yields and may promote leaching and denitrification (Steele *et al.*, 1982). Therefore a quantitative recommendation procedure for N fertilizer application is crucial in predicting the amount of N required to achieve the both optimum maize yield and maximum financial return.

2.3 Maize response to Nitrogen fertilizer application

Maize is the first most important cereals cultivated in Tanzania. Maize is cultivated on average of two million hectares, which is about 45 percent of the cultivated land. It is projected that land under maize cultivation will double by 2050 (Katinila *et al*., 1998) and fertilizer application will double as well. However, most of the small scale farmers have an average land area of about 1-2 hectare for cultivation of food and cash crops. In order to increase production, fertilizer application is worth. For instance a study by Maniafu and Kinyamario (2007) reported an increase in maize yield by 50 percent through fertilizer application in semi-arid areas of Kenya. Muhammad *et al*., (2004) also reported that increase in N fertilization resulted in an increasing above ground dry biomass of maize. Similarly Ayub *et al*., (2002) reported that increasing the levels of nitrogen in the soil showed increasing above ground dry biomass of maize.

Plants absorb N as both nitrate (NO_3^-) and ammonium (NH_4^+). These ions (NO_3^- and NH_4^+) move more in to plant roots by mass flow and diffusion (Tisdale *et al*., 1993 and Havlin *et al*., 2003). N deficient plants; become stunted and yellow in appearance. The loss of protein N from chloroplast in older leaves produces the yellowing of chlorosis, which is indicative of N deficiency (Havlin *et al*., 2003). Chlorosis usually appears first on the lower leaves; while the upper leaves remain green; and under severe N deficiency, lower leaves turn brown and die. This necrosis begins at the leaf tip and progresses along the midrib until the entire leaf is dead (Tisdale *et al*., 1993).

2.4 Nitrogen Fertilizer Recommendations for maize in the Tropics

Nitrogen fertilizer recommendation varies due to length of growing season, amount of rainfall and crop varieties. In Western Kenya with rainfall throughout the year, the N recommendation ranges from 20 to 50 kg N /ha (FAO – STATISTICS, 2004). In Uganda, a recommended dose for high yield maize crop is 50 to 90 kg N /ha (Oluoch – Kosura *et al*., 1999). In Tanzania, N fertilizer recommendations in Southern highlands with cool temperatures, high rainfall and long growing season is 60 to 100 kg N/ ha (Ndomba, 2013). For Northern Tanzania with high altitudes, cool to warm temperature and medium to high rainfall the N fertilizer recommendation is 20 to 40 kg 22N/ ha, while for Eastern zones it is recommended to use 60 to 100 kg N/ ha and for the Lake zones 80 to 100 kg N/ ha (Kanyeka *et al*., 2007). The range of fertilizer recommendations within agro-ecological zone is due to soil-climate variations in the area. The available fertilizer recommendations for N are basically blanket recommendation without consideration of variations in soil N in farms based on management practices and soil properties. Thus, there is a need to determine the N fertilizer rates to apply for maize production based on the NO_3 in the soil to achieve highest maize yield.

Use of PPNT to adjust N fertilizer rates in Winsconsin, resulted in 89% of sites received correct N application rates for maize and reduced excessive N application by 67% (Bundy and Andraski, 1995). The high yields of maize in US have been reported to be associated with the adjusted N fertilizer recommendation based on soil nitrate test results. Different states in US including Iowa, New Jersey and Wisconsin have established different N fertilizer rates (adjusted recommendation) based on the soil nitrate test results (Magdoff *et al.,* 1990; Binford *et al.,* 1992; Meisinger *et al.,* 1992; Heckman *et al.*, 1996; Bundy and Andraski, 1995). Thus a soil NO_3 test has potential to improve N fertilizer recommendation without compromising crop yields.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

This study was conducted in Morogoro Rural district in Morogoro region, Tanzania. Morogoro Rural district is located in mid-south eastern part of Tanzania between Latitudes 05°58″ and 10° 0″S and Longitudes 35°25″ and 35° 30″E. The mean annual rainfall is 600 mm in lowlands and 1,200 mm in highlands. The altitude range in the mountain landscape is between 800 to 2,400 m a.s.l and 400 to 800 m a.s.l in lowlands. The mean temperature is 18°C in highlands and 30°C in lowlands. The soils of the eastern Morogoro Rural District are strongly acid to alkaline and are classified into eight major soil types namely Lixisols, Leptosols, Luvisols, Acrisols, Cambisols, Phaeozems, Fluvisols and Regosols (Msanya *et al.,* 2001).

Two villages namely; Mikese and Kiziwa were selected based on their major Agro ecological zones (AEZ). The Kiziwa village is located at 6° 52″ S and 37° 51″ with the average temperature of 25.4°C and mean annual rainfall of 1400 mm. The climate for Kiziwa village is tropical. More rainfall is received during the long rainfall season (masika) than during the short rainfall season (vuli) in Kiziwa village. Mikese village is located between Latitudes 06° 41'' S and Longitude 37° 45'' E. The climate for Mikese village is hot and humid all the year round. Mikese receives rainfall from October to May, the area is in the 700 – 1000 mm rainfall belt, the driest months are June, July August and September (Msanya *et al*., 2001)

3.2 Soil sampling and preparation

Before setting the field experiments, 60 representative farms from the two villages were selected for soil sampling. Soil samples were collected at farmers' field where maize was to be grown. Composite samples were collected at pre planting. In each farm, composite soil samples were collected at the depths of 0 to 15 cm and 15 to 30 cm. Twenty days after sowing (DAS) and just before topdressing (at pre-topdressing), second soil sampling was conducted in 24 farms from both villages that were selected for conducting field experiments based on initial soil NO_3-N levels. The pre-topdressing composite soil samples were collected from same areas in the same way as during pre-planting to determine available N in soil at V6 stage of growth at 21 days after planting. Each composite soil sample consisted of 8 to 10 subsamples randomly collected in a farm of about 0.25 ha. The samples were air dried ground and sieved to pass through a 2 mm sieve and were analyzed in the soil and plant laboratory at Department of Soil and Geological Sciences, SUA.

3.3 Soil analysis

The soil samples were analyzed by using the 0.01 M Calcium Chloride as an extraction reagent in a 1:2 soil: extraction solution ratio as per procedures described in Weil and Gatere (2014).The extract was used to determine soil nitrate, exchangeable potassium, active carbon, sulphur and the pH as per Soil Doc Protocol (Weil and Gatere, 2014). The soil samples collected 21 days after planting were analysed for soil NO_3-N only.

The pH was determined from the settled solution by using the pH meter at 1:2 soil:water ratio. Soil NO_3 - N was determined in 0.01 $CaCl_2$ by electrode method using the NO_3- meter as per procedure described in Weil and Gatere (2014). The extractable phosphorus was extracted by using the Molybdate Blue phosphate reagent (Hanna Phosphate reagent (HI 736-25) as a color developer. Absorbency was measured by a Hanna Checker Phosphorus ULR (ppb) model HI 736 and Phosphate meter (ppm) model HI 713 after the color had fully developed with appropriate standards. Soluble S content in soil was determined by using the Barium Chloride solution and the quantified by Hanna Checker or Phosphate meter (ppm) model HI 713 (Weil and Gatere 2014).

The active C was determined by wet method using the dilute $KMNO_4$ solution. The quantity of active C in the soil was measured by using the Hanna Checker or Phosphate meter (ppm) model HI 713. (Weil and Gatere 2014). The exchangeable potassium ions in 0.01 M $CaCl_2$ at 1:2 extract was determined by electrode method using the K^+ meter (B-731) as per procedures.

3.4 Field experiment.

3.4.1 Experimental materials

The test crop used was maize variety SEEDCO which was preferred because of its tolerant to drought, has a short time to maturity (75-90 days) and is well known to most farmers in the study sites. The fertilizers used were Diammonium phosphate (DAP) (46% P and 18% N) to supply Nitrogen and Phosphorus at planting, Urea (46% N) and Sulphate of Ammonium (SA) (21% N and 23% S) were applied to supply N and S respectively at topdressing. All fertilizers were from YARA. All research materials were obtained from the local Agro-dealers stores in Morogoro town.

3.4.2 Planting and crop management

Two seeds were planted in a space of 0.75 m by 0.30 m. One plant per hole was left after thinning at 21 days after emergence. During the growth and development stages of the maize plants starting from germination all the agronomic and plant management practices were done accordingly.

Nitrogen in the starter fertilizer (DAP) was applied at planting holes at 4 cm depth and then covered with soil before planting seeds. Top dress N was applied prior to tasseling (21 days after sowing) as UREA. The amount of top dress N applied was subtracted from both the starter N and N from the SA fertilizer. Phosphorus and S were applied at constant rates, 40 kg/ha and 20 kg/ha respectively because all experiment farms had low P and S.

3.5 Treatments and experimental design

Ploughing and harrowing was done by a tractor to most of plots and to some farms were done by hand hoe. Plots of 5 m by 3 m were laid out leaving 1.5 m space between the blocks and 1 m between the plots. Out of 60 farms from both villages, 24 farms (10 experiments in Kiziwa and 14 experiments in Mikese villages) were selected based on the pre planting soil nitrate test results and the field trials were conducted. After soil NO_3 test results the farms were categorized into two groups, those with medium NO_3-N (65-90 mg/kg) and those with high NO_3-N (90-120 mg/kg) as per Soil Doc protocol. Each field experiments consisted of three treatments: (i) no N (control) (ii) half N rate (40 kg/ha) and (iii) full N rate (80 kg/ha). The treatments were randomly assigned in each farm based on the soil NO_3-N levels such that in each NO_3 level group there were all three treatments. The treatments were replicated three times. During seedbed preparation, the experiment farm was subdivided into 6 plots in three blocks, of which the three treatments were randomly assigned in each block, thus, the experiment farm was established as a randomized complete block design.

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3.6 Plant sampling

3.6.1 Whole plant sampling

The above ground portions of the maize plants were sampled when the maize plants were at brown silking stage of growth. The plants were harvested from an area of 2 m^2 at each plot which constituted nine plants from central columns and rows. The plants were harvested by cutting at 1 cm above the soil surface from each sub plot within the harvest area. The fresh weight under field condition was measured using an electronic weighing balance. Then a subsample of four plants was randomly selected from the whole plant sample from each plot and weighed. The subsamples were taken to Sokoine University of Agriculture (SUA) air dried and weighed to determine biomass yield (dry matter yield).

3.6.2 Leaf sampling and sample preparation

Ten ear leaves were randomly sampled from each plot and each sample was packed in a clean and labeled paper envelope. The sent to SUA laboratory for further processing and analysis of different nutrients. At SUA leaf samples were washed and then air dried in a dust free screen house then the maize ear leaves were oven dried and ground to fine powder by plant grinder.

3.6.3 Grain yield determination

Maize cobs from the 2 m^2 harvested area were air dried and shelled. The maize grains were air dried followed by oven drying to adjust moisture content to 14%. The dried maize grains from each plot were weighed and the weight per each harvested area (2 m^2) was expressed in tonnes per hectare (t ha^{-1}).

3.6.4 Plant samples analysis

Plant samples were digested using the Micro-Kjeldahl wet oxidation procedure of Kalra (1998). A 0.2 g of ground plant sample was weighed and transferred to 350 ml Kjedahl tubes. The sample was added with 2 g of mixed catalyst made up of Copper sulphate ($CuSO_4$, Pottasium sulphate (K_2SO_4) and Selenium (Se) followed by concentrated H_2SO_4 and shaken gently until all the plant sample and acid were thoroughly mixed. The digestion tubes were then placed on the digestion block with temperature set at 125^oC for 2 hours, then taken off and cooled. After cooling 50 ml of boric acid was mixed with methyl orange indicator for distillation. Two hundred millilitres of the distillate was collected and titrated with 0.05N H_2SO_4 to a pink color end point.

3.7 Data analysis

Data on maize yield (grain yield and dry matter yield) were subjected to Analysis of Variance (ANOVA) as per Randomized Complete Block Design in a split plot using SAS software version 9.0 (SAS Institute Inc. Cary, NC, USA, 2002). The main plot was the initial NO_3-N before planting (NO_3-level) and the split plot was N fertilizer rate. A separate ANOVA to determine effect of time of sampling for NO_3 test and

NO_3 level on maize growth was also done. Where significance existed mean separation was done using Fisher's Least Significance Difference (LSD) at alpha = 5%.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Chemical properties of soils of Mikese and Kiziwa

The chemical properties of soils from selected farms in Kiziwa and Mikese villages used in this study are shown in Table 1 (Appendix 1). The mean soil pH was 6.4 ranging from 6.2 to 7.1 in the top soil and 6.4 in the sub soil ranging from 6.1 to 7.1 for Kiziwa village. In Mikese the mean soil pH was 6.7 and range from 6.3 to 7.1 in the top soil, and 6.1 to 7.1 in the subsoil. (Table 1). According to Landon (1991) pH values are classified into four classes, values >8.5 as very high, 7 to 8.5 as high, 5.5 to 7 as medium and <5.5 as low. From the results in Table 1 the soil pH values for all studied soils fall in the medium class. These soils are slightly acid to slightly basic at both top and sub soil in both villages. The soil pH for these soils is optimal for the growth of most crops.

The mean available phosphorus in Kiziwa village soils was 0.17 mg kg^{-1} and ranged from 0.1 to 0.6 mg kg^{-1} and 0.1 to 0.6 mg kg^{-1} in the top soil and subsoil respectively (Table 1). In Mikese village the available P on top soil had a mean of 0.1 mg kg^{-1} with a range of 0.1 to 0.6 mg kg^{-1} while in subsoil ranged from 0.1 to 0.3 mg kg^{-1}. In Kiziwa village the mean available S in soil was 4.4 mg kg^{-1} (range 2.4 to 10 mg kg^{-1}) and the mean of 3.9 mg kg^{-1} ranging from 2.4 to 6.4 mg kg^{-1} in the top and subsoil respectively. According to the SoilDoc protocol the available P in the top and subsoil of both villages are categorized as low (0.1 to 0.3 mg P kg^{-1}) which is insufficient for the maize growth. The available S was also very low (< 5 mg kg^{-1}) for all soils in both village (Soil Doc 2016, unpublished guidelines).

Table 1: **The range, mean and standard deviation of chemical properties of soils of selected farms in Mikese and Kiziwa villages**

Village	N	Depth	Soil pH (H2O)	Avail P (mg kg-1)	K (mg kg-1)	Avail S (mg kg-1)	Active C (mg kg-1)
Kiziwa	**20**	**0 – 15**	6.2 to 7.1 (6.4; 0.2)	-0.1 to 0.6 (0.17;0.18)	8 to 110 (45.2;32.7)	2.4 to 10.00 (4.4;1.4)	99 to 1326 (710;203)
		Category	Medium	Low	High	Very low	Extremely high
	20	**15 – 30**	6.1 to 7.1 (6.4;0.3)	-0.1 to 0.6 (0.1;0.2)	4 to 66 (19.7;18.2)	2.4 to 6.4 (3.9;0.7)	487 to 1112 (768;156)
		Category	Medium	Low	Low	Very low	Extremely high
Mikese	**28**	**0 – 15**	6.3 to 7.1 (6.7;0.3)	-0.1 to 0.5 (0.1;0.2)	24 to 154 (91;35)	-2.2 to 5.5 (3.8;1.3)	99 to 1041 (677;205)
		Category	Medium	Low	Very high	Very low	high
	28	**15 – 30**	6.2 to 7.1 (6.7;0.2)	-0.1 to 0.3 (0.1;0.1)	6 to 148 (61.7;42.5)	-2.2 to 5.6 (3.9;1.3)	194 to 1358 (606;225)
		Category	Medium	Low	Very high	Very low	high

n=number of observations; Number in parenthesis are mean; standard deviation

The mean exchangeable K^+ was 45.2 mg kg^{-1} ranging from 8 to 110 mg kg^{-1} in the topsoil and the mean of 19.7 mg kg^{-1} ranging from 4 to 66 mg kg^{-1} in the subsoil in Kiziwa village (Table 1). The top and sub soil of Mikese village had the mean exchangeable K^+ of 91 mg kg^{-1} ranging from 24 to 154 mg kg^{-1} and the mean of 61.7 mg kg^{-1} ranging from 6.0 to 148 mg kg^{-1} in the top and subsoil respectively (Table 1). The Soil Doc protocol classifies exchangeable K^+ as very low (<= 10 mg kg^{-1}), low (10 to 20 mg kg^{-1}), medium (20 to 40 mg kg^{-1}), high (40 to 60 mg kg^{-1}) and very high (>60 mg kg^{-1}). The exchangeable potassium was very high for most of the top soils in both villages. The mean active C was 710 mg kg^{-1} and ranged from 99 to 1326 mg kg^{-1} in the topsoil while in the subsoil the mean was 768 mg kg^{-1} and ranged from 487 to 1112 mg kg^{-1} in Kiziwa village. The active C average was 677 mg kg^{-1} with a range of 99 to 1041 mg kg^{-1} in the topsoil and 606 mg kg^{-1} with range of 194 to 1358 mg kg^{-1} in the subsoil of Mikese village (Table 1). The results showed that the active carbon for all studied soils were extremely high (>700 mg kg^{-1}) for Kiziwa village and high (500 to 700 mg kg^{-1}) for Mikese village (Appendix Table 1).

Adequate soil chemical environment and concentration of essential nutrients in soils are important for proper growth, nutrient availability and absorption for plant growth. Exchangeable K was sufficient for most of the top soils. A study by Msanya *et al*, (1999) also found the medium to high levels of exchangeable K. Although all farms had optimum soil pH for crop growth, the results showed P and S was deficient in both villages, and were previously reported by Msanya *et al.*, (1999). This implies that the application of P and S fertilizers is necessary in these soils for optimal growth of crops.

4.2 Changes of soil NO_3-N concentration over season critical time for N requirements for plant development

Maize crop needs significant amounts of N at different growth stages. Nitrogen is required at planting and after the crop establishment. The soil NO_3 levels at 0 to 15 cm and 15 to 30 cm depth for pre-planting and pre-top dressing are shown in Table 2. The average level of NO_3-N at pre planting sampling (PPNT) was 40 mg kg^{-1} in the topsoil and 25 mg kg^{-1} in the subsoil (Table 2). The mean NO_3 level at pre topdressing time (PTNT) was 175 mg kg^{-1} in the topsoil and 148 mg kg^{-1} in the subsoil. The soil NO_3-N changes from initial sampling at pre-planting to pre-topdressing were positive in both depths, with an increase of 135 mg kg^{-1} in the top soil and 123 mg kg^{-1} in the subsurface (Table 2), indicating an increase of NO_3-N in the soil as the season progressed up to 20 DAS. The magnitude of change in NO_3-N in soil was slightly greater in the sub soil (71%) than in the topsoil (63%) (Table 2).

Table 2: Changes of Soil NO3-N Concentration over Season Critical time for plant development

Soil depth (cm)	Time of sampling	n	Soil NO_3-N (mg kg^{-1})	Change in Soil NO_3-N over time
Topsoil (0 – 15)	Pre planting	24	40	135
	Pre-topdressing	24	175	
Subsurface (15 – 30)	Pre planting	24	25	123
	Pre-topdressing	24	148	

n = number of sites

According to Soil Doc Protocol the NO_3-N is categorized as very low (<=21 mg kg^{-1}), low (21 to 42 mg kg^{-1}), medium (42 to 65 mg kg^{-1}), medium-high (65 to 90 mg kg^{-1}), high (90 to 120 mg kg^{-1}) and very high (>120 mg kg^{-1}). At PPNT most sites fell in medium and high category but at PTNT the levels increased and all the sites fell in very high NO_3-N category. The increase in NO_3-N levels is probably due to sufficient time for organic N mineralization and nitrification from organic matter and decomposition of residual organic N from previous season as the season progressed. This was also reported by Bundy *et al*. (1999) where 75% of his study sites exhibited an increase in NO_3-N concentration.

The high level of NO_3-N in the top soil than subsoil imply that there was a readily available NO_3-N for crop uptake in the top soil which might have been resulted from decomposition of organic matter in the soil surface. The low NO_3-N in the subsoil during both sampling time shows that there was less leaching of NO_3-N. Less leaching might be due to low and erratic rains received in both villages during the 2016 growing season from mid-Feb to mid-March 2016. These findings are consistent with the results by Bundy *et al*., (1999) where they found higher accumulation of NO_3-N within 30-cm than in 60-cm depth in the North Central Region of US.

4.3 Response of maize to the applied N fertilizer rates at different soil N levels

Nitrogen fertilizer rate significantly ($p < 0.0001$) affected fresh weight, dry weight and grain yield (Table 3). Soil NO_3 level and the interaction of soil NO_3 level by N rate had no significant effect on the maize growth yield (Table 3). Village differed significantly in maize grain yield only (Table 3). Lack of significant interaction between soil NO_3 and N rate shows that the response of maize to N fertilizers is the same regardless of concentration of NO_3 -N in the soil. This implies that the levels of NO_3 -N in the soil whether high or medium did not account for the yield that's why there was no significant difference in response of maize to applied N fertilizer at different NO_3 - N levels. This is different from what was observed by Cui *et al*., (2008) where there was a significant response of maize to applied N fertilizer at different soil nitrate levels.

The full rate of N fertilizer at 80 kg N ha^{-1} recorded the highest fresh weight yield of 5.87 kg $plot^{-1}$, dry weight of 0.57 kg $plot^{-1}$, grain yield of 1.81 t ha^{-1} and total plant N concentration of 1.36 % (Figure 2). The lowest yield was recorded at 0 kg N ha^{-1} (the control) where the fresh weight was 3.49 kg $plot^{-1}$, dry weight was 0.36 kg $plot^{-1}$, grain yield was 0.8 t ha^{-1} and the plant total N was 1.25% (Figure. 2)

Table 3: Summary of Analysis of Variance (ANOVA) on the effect of Soil NO3 level and N fertilizer rate on maize growth and yield at Morogoro Rural district

Source of variation	Df	Fresh weight	Dry weight	Grain yield	Plant TN
			p-values		
Soil N Level	1	0.3282	0.3532	0.9984	0.3998
N Rate	2	<.0001	0.0019	<0.0001	0.0778
Soil NO_3 level*N Rate	2	0.7337	0.4906	0.7054	0.8241
Village	1	0.3920	0.3933	0.0011	0.0607
Overall model	6	<0.0001	0.0080	<0.0001	0.0387

*Key: Df- degree of freedom

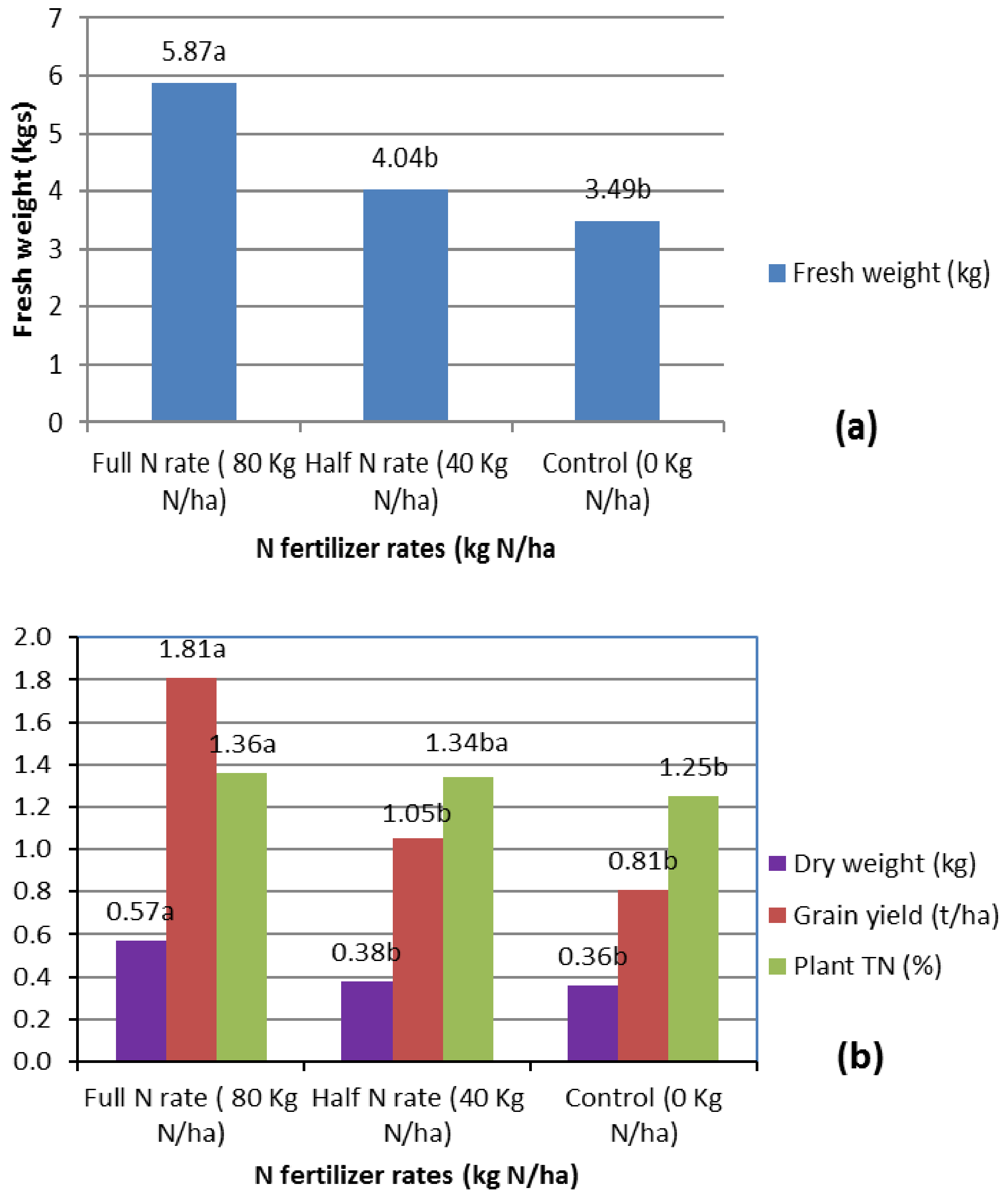

Figure 2: Effect of N Fertilizer Rates on: a) Maize Fresh Weight b) Dry Weight, Grain Yield and Plant Total N

Means followed by the same letters in the same column are not significantly different 5 % level of significance; N- number of observations; $LSD_{0.05}$ – Least Significant Difference at 5% level of significance

The highest yield in high N fertilizer rate was promoted by adequate nitrogen supply through N fertilization at full N rate of 80 kg N ha^{-1}. These results are similar to the Matusso's (2015) where the highest maize grain yield of 1.14 t ha^{-1} was attained at the highest N fertilizer rate of 49 N kg ha^{-1} where the low maize grain yield of 0.25 t ha^{-1} and 0.42 t ha^{-1} were attained where no N fertilizer was applied (0 kg N ha^{-1}) and 25 kg N ha^{-1} rates, respectively. Khan *et al.*, (2012) showed that increase of nitrogen levels enhanced final seed yield due to increase of seed number in each ear and so they recorded the greatest grain yield of maize of 1.5 t ha^{-1} under the 160 kg ha^{-1} N level. A study by Zelalem (2013) reported that N application increased the grain yield of maize and application of 100 kg N ha^{-1} gave the highest grain yield of 5.9 t ha^{-1} as compared to the control treatment (0 kg N ha^{-1}).

Similarly, Mosisa *et al*. (2007) reported that the application of N increased grain yield of hybrid maize varieties under optimal condition of soil nitrogen level. The results shows that the different levels of soil NO_3-N had no effect on maize response to applied N fertilizer rates. Therefore the use of N fertilizer is worth for optimum maize yield.

4.4 Best Sampling Time for Soil N Testing

The results showed no significant effect of time of NO_3 sampling for NO_3-N testing by soil NO_3-N level combination on maize growth and yield (Table 4). Also the combination of time of NO_3 test –NO_3 level by N rate was not significant at ($p<0.05$). Village significantly differed in grain yield (Table 4). Thus, there was no significant difference in maize response to applied N fertilizer between two sampling times of soil NO_3 testing (Table 6).

Table 4: Effect of combination of time of N test and soil N level by N rate on the maize fresh weight, dry weight grain yield and total N

Source of variation	Df	Fresh weight *p*-values	Dry weight	Grain yield	Plant TN
Time NO_3 test-Soil N level	2	0.5920	0.6851	0.9808	0.0866
N Rate	2	<0.0001	0.0009	<0.0001	0.0313
Time NO_3 test-Soil N level*N rate	4	0.9113	0.5673	0.9116	0.8079
Overall model		<0.0001	0.02977	<0.0001	<0.0516

The maize response to applied N fertilizer rates as determined by time of sampling and soil NO_3 level is shown in Table 5. Although not statistically different, the results show that the medium soil NO_3 level at pre-planting that received full rate of N gave highest response of 0.63 kg for dry weight, 2.03 t ha^{-1} for grain yield, 1.32 for plant total N and 5.99 kg for fresh weight (Table 5). At pre planting sampling with high soil NO_3^- level and with full rate of N fertilizer the response was 0.51 kg for dry weight, 1.58 t ha^{-1} for grain yield, 1.41% for plant total N and 5.75 kg for fresh weight (Table 5). Likewise the response results at half rate of N fertilizer were all the same at different time of N test by N level combination. All maize yield responses measured were lowest when no N fertilizer was applied regardless of soil NO_3 level and time of sampling (Table 5).

Table 5: Effect of Combination of Time of N Test and N Level by N Rate and the Maize Fresh Weight, Dry Weight, Grain Yield and Total N.

Time N test- Soil N level	N rate	N	Dry weight (kg)	Grain yield (t ha^{-1})	Plant TN	Fresh weight
Pre-planting-medium	Full	18	0.63	2.03	1.32	5.99
Pre-planting-medium	Half	18	0.33	1.17	1.24	3.31
Pre-planting-medium	No N	36	0.50	0.94	1.18	3.52
Pre-planting- high	Full	18	0.51	1.58	1.41	5.75
Pre-planting- high	Half	18	0.43	0.93	1.45	4.76
Pre-planting –high	No N	36	0.31	0.68	1.31	3.45
Post-planting-high	Full	36	0.57	1.03	0.43	5.87
Post-planting-high	Half	36	0.38	0.83	0.33	4.04
Post- planting-high	No N	72	0.36	0.82	0.31	3.48
$LSD_{0.05}$			0.03	<0.00	0.05	<0.00

Key; N-number in parentheses

Although the NO_3 test and ratings by Soil Doc protocol showed that the soils have sufficient N levels at both times of sampling (i.e. medium and high soil NO_3), all soils responded to N fertilizer application. Based on these results, either pre-planting or pre-topdressing sampling time can be adopted to guide N fertilization because there was no significant difference in response between the two sampling times on applied N fertilizer rates as far as this study is concerned. Lack of differences in response due to time of sampling obtained in this study is consistent with the results by Bundy *et al*., (1999) when alfalfa was the previous crop to maize but there was an increase in soil NO_3-N by pre topdressing sampling. Therefore based on these results, both times of sampling can were not helpful in predicting the N requirements of the crop.

However a study by Steele *et al*., (1982) suggested the best time to sample mineral N for prediction of fertilizer requirement is at the time of maximum accumulation of mineral N in soils, which normally occurs in the beginning of rain season before crop demand exceeds the rate of N mineralization. This implies that further studies on the best sampling time for N fertilizer requirements has to be conducted.

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The village's differences in the grain yield might have been associated with the different soil chemical properties (Appendix Table 1) and the climatic condition between villages. Both villages had erratic rainfall during the growing season. Also the different management practices at the two villages might have contributed to these results. This opens the door for more studies on the effect of time of N testing and soil NO_3 level to be done at different geographic areas.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Considering all results it can be concluded that

- There was an increase in soil NO_3-N over the growing season at both study areas. This implies that there was no need to apply N fertilizer to these soils because the NO_3-N levels were sufficient for maize growth. However this increase in soil NO_3-N levels did not affect the maize response to applied N fertilizer and that's why for optimum maize yield; the application of N fertilizer becomes worth for these soils.

- The vulnerability of NO_3-N sampling strategies to soil and climatic variations affect the potential for soil NO_3-N losses, soil N mineralization and crop N demand. Therefore based on this study both time of sampling (PPNT and PTNT) were not helpful to predict N fertilizer requirement for maize production in the tropics because at both time of sampling there was no significant difference in maize response to applied N fertilizer.

5.2 Recommendations

- Nitrogen fertilizer at a rate of 80 kg N ha^{-1} , which is the current official recommended rate for N in eastern zone is optimum for maize growth and yield in tropical soils with medium to high soil NO_3-N
- Evaluation of the soil Nitrate- N test needs to be continued over various tropical soils, locations and weather patterns to establish its usefulness in guiding N fertilizer needs.

- Further studies to evaluate categorization of soil NO_3 level in tropical soils and under short growing season should be conducted.

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APPENDICES

Appendix 1: Chemical properties of the selected sites of Kiziwa and Mikese villages in Morogo rural district.

village	Farmer's name	Sampling depth(cm)	Sampling time	PH_{H2O}	Nmgkg^{-1}	NO3-N mgkg^{-1}	K mgkg^{-1}	K cmol	P mg P kg^{-1}	S mg S kg^{-1}	Active_C_mgkg
Mikese	Abdalah Tambaone	0-15	PPNT	6.94	16.26	72.00	102.00	0.26	0.30	3.045279	874.8
Mikese	Abdalah Tambaone	15-30	PPNT	6.68	9.94	44.00	30.00	0.08	0.20	3.135682	581.8
Mikese	Tegemea Maketa	0-15	PPNT	6.35	18.52	82.00	96.00	0.25	0.00	4.03971	740.2
Mikese	Tegemea Maketa	15-30	PPNT	6.80	9.48	42.00	68.00	0.17	-0.10	4.130113	700.6
Mikese	Hassan Kalungwana	0-15	PPNT	6.43	15.81	70.00	138.00	0.35	0.10	5.486155	803.5
Mikese	Hassan Kalungwana	15-30	PPNT	6.34	11.29	50.00	56.00	0.14	0.00	5.034141	589.7
Mikese	Rebecka Lazaro	0-15	PPNT	6.88	20.32	90.00	88.00	0.23	0.30	3.949308	526.3
Mikese	Rebecka Lazaro	15-30	PPNT	6.88	7.23	32.00	88.00	0.23	0.00	3.587696	676.8
Mikese	Mwalim Mstaafu	0-15	PPNT	6.90	21.68	96.00	122.00	0.31	0.10	4.03971	1041.1
Mikese	Mwalim Mstaafu	15-30	PPNT	6.91	13.10	58.00	148.00	0.38	0.00	4.03971	637.2
Mikese	Julius Mahanga	0-15	PPNT	6.69	8.58	38.00	24.00	0.06	0.10	2.864474	661.0
Mikese	Julius Mahanga	15-30	PPNT	6.37	2.71	12.00	6.00	0.02	0.00	3.135682	193.7
Mikese	Fatuma Mkombozi	0-15	PPNT	6.91	12.19	54.00	114.00	0.29	0.40	3.768502	859.0
Mikese	Fatuma Mkombozi	15-30	PPNT	6.81	4.06	18.00	56.00	0.14	-0.10	3.678099	621.4
Mikese	Mwajuma Kawanga	0-15	PPNT	6.36	10.39	46.00	154.00	0.39	0.30	4.401322	811.4
Mikese	Mwajuma Kawanga	15-30	PPNT	6.83	17.61	78.00	108.00	0.28	0.20	4.130113	534.2
Mikese	Evans Jonas	0-15	PPNT	6.93	11.74	52.00	112.00	0.29	-0.10	3.949308	724.3
Mikese	Evans Jonas	15-30	PPNT	6.79	13.55	60.00	52.00	0.13	0.20	3.497293	676.8
Mikese	Yahya Ghana	0-15	PPNT	6.75	13.55	60.00	50.00	0.13	0.40	3.135682	692.6
Mikese	Yahya Ghana	15-30	PPNT	6.68	-0.90	-4.00	16.00	0.04	0.30	3.587696	581.8
Mikese	Sudi Abdalla	0-15	PPNT	6.33	9.03	40.00	52.00	0.13	0.30	4.130113	906.5
Mikese	Sudi Abdalla	15-30	PPNT	6.34	1.81	8.00	16.00	0.04	0.10	4.401322	534.2
Kiziwa	Rajabu Mahumiza	0-15	PPNT	6.29	12.19	54.00	38.00	0.10	0.30	4.310919	740.2
Kiziwa	Rajabu Mahumiza	15-30	PPNT	6.78	2.71	12.00	14.00	0.04	0.10	4.03971	676.8

Mikese	Nimuzihilwa Yoeli	0-15	PPNT	6.90	9.94	44.00	118.00	0.30	0.20	4.310919	692.6
Mikese	Nimuzihilwa Yoeli	15-30	PPNT	6.90	3.61	16.00	138.00	0.35	0.10	3.678099	859.0
Kiziwa	John Yulian	0-15	PPNT	6.38	2.71	12.00	64.00	0.16	0.30	4.582127	930.2
Kiziwa	John Yulian	15-30	PPNT	6.29	3.61	16.00	36.00	0.09	0.00	3.949308	811.4
Kiziwa	Hidaya Saidi	0-15	PPNT	6.40	0.45	2.00	8.00	0.02	0.20	4.310919	787.7
Kiziwa	Hidaya Saidi	15-30	PPNT	6.29	0.00	0.00	6.00	0.02	0.20	4.491724	819.4
Kiziwa	Issa Hossein	0-15	PPNT	6.30	0.45	2.00	26.00	0.07	0.40	4.762933	779.8
Kiziwa	Issa Hossein	15-30	PPNT	6.40	0.00	0.00	12.00	0.03	0.40	3.768502	882.7
Kiziwa	Anania Peter	0-15	PPNT	6.20	4.52	20.00	18.00	0.05	0.40	4.130113	716.4
Kiziwa	Anania Peter	15-30	PPNT	6.20	0.00	0.00	6.00	0.02	0.30	6.480586	946.1
Kiziwa	Adam Kamuite	0-15	PPNT	6.30	4.06	18.00	110.00	0.28	0.60	4.762933	740.2
Kiziwa	Adam Kamuite	15-30	PPNT	6.30	11.74	52.00	66.00	0.17	0.30	3.858905	961.9
Kiziwa	Mariam Ramadhani	0-15	PPNT	6.40	4.52	20.00	54.00	0.14	0.00	4.491724	827.3
Kiziwa	Mariam Ramadhani	15-30	PPNT	6.30	3.61	16.00	18.00	0.05	-0.10	3.949308	985.7
Mikese	Kawanga Mohamed	0-15	PPNT	6.40	5.42	24.00	146.00	0.37	0.20	2.864474	819.4
Mikese	Kawanga Mohamed	15-30	PPNT	6.50	4.06	18.00	84.00	0.22	0.20	4.853336	328.3
Mikese	Aroni Daniel	0-15	PPNT	6.40	3.16	14.00	48.00	0.12	0.10	4.582127	795.6
Mikese	Aroni Daniel	15-30	PPNT	6.20	9.48	42.00	8.00	0.02	0.00	4.03971	748.1
Kiziwa	Tatu Shomari	0-15	PPNT	6.30	5.42	24.00	106.00	0.27	0.10	10.0063	851.0
Kiziwa	Tatu Shomari	15-30	PPNT	6.40	1.35	6.00	66.00	0.17	0.10	3.587696	700.6
Kiziwa	Abdala Maundi	0-15	PPNT	6.30	4.06	18.00	32.00	0.08	0.00	4.130113	993.6
Kiziwa	Abdala Maundi	15-30	PPNT	6.40	0.90	4.00	14.00	0.04	0.20	4.03971	1112.4
Kiziwa	Milomo Hossein	0-15	PPNT	6.20	1.35	6.00	10.00	0.03	-0.10	4.853336	1326.2
Kiziwa	Milomo Hossein	15-30	PPNT	6.30	4.52	20.00	6.00	0.02	0.00	3.678099	787.7
Mikese	Abdalah Tambaone	0-15	PTNT	6.39	62.77	278.00	92.00	0.24	0.20	4.491724	98.6
Mikese	Abdalah Tambaone	15-30	PTNT	6.87	25.29	112.00	22.00	0.06	0.20	3.587696	265.0
Mikese	Tegemea Maketa	0-15	PTNT	6.90	24.39	108.00	70.00	0.18	0.10	4.220516	653.0
Mikese	Tegemea Maketa	15-30	PTNT	6.80	26.65	118.00	128.00	0.33	0.00	4.853336	676.8
Mikese	Hassan Kalungwana	0-15	PTNT	6.80	44.71	198.00	136.00	0.35	0.10	3.858905	882.7
Mikese	Hassan Kalungwana	15-30	PTNT	6.70	35.68	158.00	64.00	0.16	0.10	4.491724	573.8
Mikese	Rebecka Lazaro	0-15	PTNT	7.00	44.71	198.00	100.00	0.26	0.00	-2.19808	771.8

Mikese	Rebecka Lazaro	15-30	PTNT	6.90	42.45	188.00	94.00	0.24	0.20	-2.19808	661.0
Mikese	Mwalim Mstaafu	0-15	PTNT	7.09	35.68	158.00	102.00	0.26	-0.10	4.67253	835.2
Mikese	Mwalim Mstaafu	15-30	PTNT	7.11	35.68	158.00	112.00	0.29	0.00	4.130113	811.4
Mikese	Julius Mahanga	0-15	PTNT	6.40	40.19	178.00	32.00	0.08	-0.10	3.949308	653.0
Mikese	Julius Mahanga	15-30	PTNT	6.70	20.32	90.00	8.00	0.02	0.00	3.678099	637.2
Mikese	Fatuma Mkombozi	0-15	PTNT	7.01	30.26	134.00	82.00	0.21	0.00	4.220516	407.5
Mikese	Fatuma Mkombozi	15-30	PTNT	6.70	35.68	158.00	36.00	0.09	0.10	4.220516	565.9
Mikese	Mwajuma Kawanga	0-15	PTNT	6.90	40.19	178.00	72.00	0.18	0.20	4.03971	383.8
Mikese	Mwajuma Kawanga	15-30	PTNT	6.60	28.90	128.00	22.00	0.06	0.00	4.401322	779.8
Mikese	Evans Jonas	0-15	PTNT	6.40	31.16	138.00	128.00	0.33	-0.10	3.858905	415.4
Mikese	Evans Jonas	15-30	PTNT	6.90	35.68	158.00	100.00	0.26	0.10	4.67253	510.5
Mikese	Yahya Ghana	0-15	PTNT	6.80	35.68	158.00	96.00	0.25	0.20	4.67253	447.1
Mikese	Yahya Ghana	15-30	PTNT	6.30	35.68	158.00	30.00	0.08	0.10	3.135682	249.1
Mikese	Sudi Abdalla	0-15	PTNT	7.10	35.68	158.00	38.00	0.10	0.00	4.220516	502.6
Mikese	Sudi Abdalla	15-30	PTNT	6.70	25.74	114.00	28.00	0.07	0.00	3.587696	510.5
Kiziwa	Rajabu Mahumiza	0-15	PTNT	6.70	44.71	198.00	22.00	0.06	0.20	3.587696	661.0
Kiziwa	Rajabu Mahumiza	15-30	PTNT	6.80	40.19	178.00	12.00	0.03	-0.10	4.582127	661.0
Mikese	Nimuzihilwa Yoeli	0-15	PTNT	6.40	29.35	130.00	66.00	0.17	0.10	3.045279	518.4
Mikese	Nimuzihilwa Yoeli	15-30	PTNT	6.70	27.55	122.00	58.00	0.15	-0.10	5.576558	336.2
Kiziwa	John Yulian	0-15	PTNT	7.10	44.71	198.00	48.00	0.12	0.10	3.587696	439.2
Kiziwa	John Yulian	15-30	PTNT	7.10	31.16	138.00	22.00	0.06	0.00	3.768502	558.0
Kiziwa	Hidaya Saidi	0-15	PTNT	6.40	35.68	158.00	14.00	0.04	0.10	3.587696	470.9
Kiziwa	Hidaya Saidi	15-30	PTNT	6.30	35.68	158.00	4.00	0.01	0.10	3.678099	779.8
Kiziwa	Issa Hossein	0-15	PTNT	6.30	35.68	158.00	20.00	0.05	0.00	2.41246	565.9
Kiziwa	Issa Hossein	15-30	PTNT	6.50	31.16	138.00	4.00	0.01	-0.10	4.03971	756.0
Kiziwa	Anania Peter	0-15	PTNT	6.70	44.71	198.00	78.00	0.20	0.20	4.310919	811.4
Kiziwa	Anania Peter	15-30	PTNT	6.30	25.74	114.00	28.00	0.07	0.60	2.41246	740.2
Kiziwa	Adam Kamuite	0-15	PTNT	6.60	35.68	158.00	94.00	0.24	0.20	3.858905	565.9
Kiziwa	Adam Kamuite	15-30	PTNT	6.10	44.71	198.00	30.00	0.08	-0.10	3.858905	676.8
Kiziwa	Mariam Ramadhani	0-15	PTNT	6.30	26.19	116.00	32.00	0.08	-0.10	3.949308	621.4
Kiziwa	Mariam Ramadhani	15-30	PTNT	6.10	28.45	126.00	8.00	0.02	-0.10	3.587696	700.6

Mikese	Kawanga Mohamed	0-15	PTNT	6.70	40.19	178.00	90.00	0.23	0.30	4.03971	597.6
Mikese	Kawanga Mohamed	15-30	PTNT	6.40	35.68	158.00	110.00	0.28	0.20	4.67253	1357.9
Mikese	Aroni Daniel	0-15	PTNT	6.40	35.68	158.00	80.00	0.21	0.50	5.30535	851.0
Mikese	Aroni Daniel	15-30	PTNT	6.40	31.16	138.00	44.00	0.11	0.20	4.762933	756.0
Kiziwa	Tatu Shomari	0-15	PTNT	6.60	62.77	278.00	78.00	0.20	0.20	4.220516	843.1
Kiziwa	Tatu Shomari	15-30	PTNT	6.50	62.77	278.00	22.00	0.06	-0.10	3.587696	486.7
Kiziwa	Abdala Maundi	0-15	PTNT	6.20	49.23	218.00	46.00	0.12	0.00	3.768502	692.6
Kiziwa	Abdala Maundi	15-30	PTNT	6.70	26.65	118.00	12.00	0.03	0.20	3.316488	748.1
Kiziwa	Milomo Hossein	0-15	PTNT	6.70	35.68	158.00	10.00	0.03	0.30	4.130113	756.0
Kiziwa	Milomo Hossein	15-30	PTNT	6.30	31.16	138.00	8.00	0.02	0.20	4.069845	550.1