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# Effects of Long-Term Application of Inorganic Fertilizers on Primary Macronutrients in Trans Nzoia Maize Farm Soils, Kenya

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## ABSTRACT

The study investigated primary soil macronutrients accumulation in Kerita maize farm soils after more than 20 years of application of inorganic fertilizers. 12 samples of soil were collected from Kerita farm and 2 from a control site of Kiptuimet primary school. Nitrogen, Phosphorus and Potassium contents in soils were determined using Kjeldahl method for nitrogen analysis, UV-visible spectroscopy and flame photometry, respectively. The results revealed that maize farm soils had higher phosphorous levels with a mean concentration of 39.33±2.96 ppm compared to the control site which had mean concentration of 15 ppm. Total nitrogen in Kerita maize farm soil was lower at 0.109±0.01% compared to the control site which had 0.12±0.00%, while mean concentration of potassium in the farm soils was much depleted at 0.5433±08% compared to the control site which had 1.15±0.14%. The results suggest that long term application of inorganic fertilizers had raised soil phosphorous level in Kerita maize farm but influenced depletion of potassium and nitrogen. Although the concentration of phosphorus in the farm was considered adequate for maize cultivation, the levels of nitrogen and potassium in soils were below the required concentration hence affecting maize production in the farm. Therefore proper balancing of macronutrients is required while selecting commercial fertilizers to meet crop needs. In addition, supplementing commercial fertilizers with compost manure is recommended to boost nutrient deficiencies in the farm soils.

**Keywords:** Kerita Farm soil, Primary Macronutrients Deficiency, Impact of long-term soil fertilization.

## I. INTRODUCTION

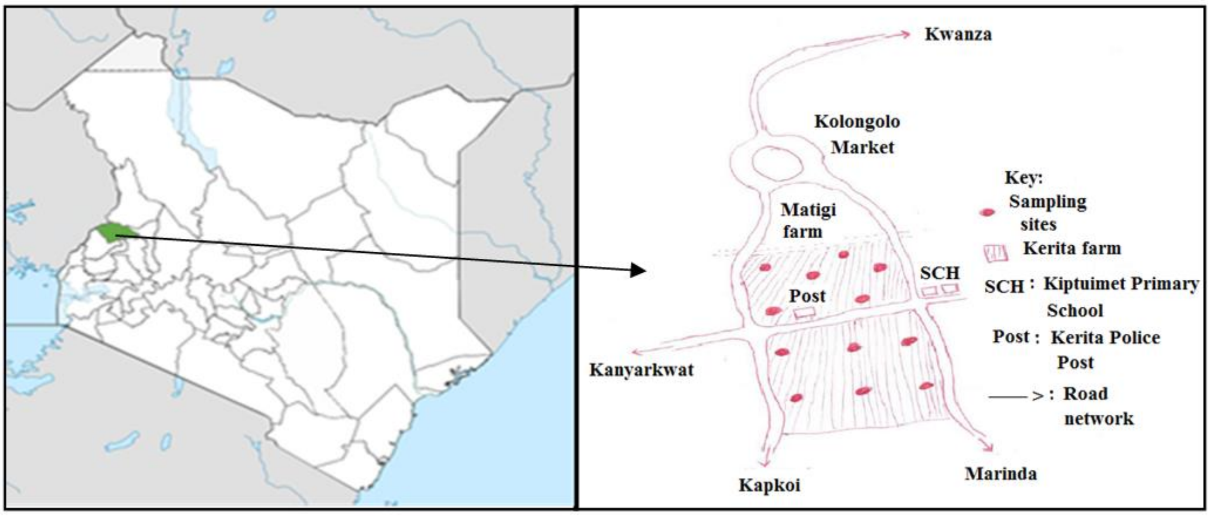
Maize is not only important for human diet but also a major component of livestock feed in Kenya. Maize production in Trans Nzoia is an important component to national food security since the region is considered the grain basket for the country. However, maize production trend in the country has been declining in the past decade[1] leading to over dependency on importation and frequent escalating market prices. Poor seed quality, land infertility and climate change and variability effects are some of the issues that have been cited as the major factors leading to low maize production.[1,2] Partly this has led to an increase in fertilizer application through government subsidies. The most commonly used fertilizers include; Di-ammonium phosphate (DAP), UREA and Calcium of Ammonium Nitrate (CAN), of which the main essential components for plant growth are nitrogen, phosphorus and potassium.[3] However, currently inadequate information is available about the impact of the long term application of these inorganic fertilizers on availability of N, P and K in the farm soils. According to some studies, inappropriate use of inorganic fertilizer for a long period of time may impair soil fertility when there is imbalanced application of nutrients.[4] In addition, some study have shown that imbalanced nutrients application of inorganic fertilizer cannot sustain the desired level of crop production.[5] Furthermore, excessive application of these fertilizers not only results into environmental and ecological problems such as eutrophication but also stimulates plant and algal growth which on decomposition deplete dissolved oxygen in the water, causing anoxic conditions. Low dissolved oxygen concentration in the water columns is detrimental to sustainability of the aquatic life, particularly the fisheries industry which is key to the country and export market.[6,7]

Some researchers have argued that immediate short-term effects of chemical fertilizers are often emphasized to the neglect of residual effects.[8] Consequently, traditional practices such as recycling organic materials, application of organic resources whose residual effects may last for many years has been abandoned. Yet residual effects of inorganic fertilizer treatments may negatively affect the soil chemical properties and consequently crop yields in the long term. In addition, the residues of inorganic nitrogen fertilizers usually last only for a season, but the residual effects of continued manuring with phosphorus, nitrogen and potassium may last for many more years.[9]

## II. MATERIALS AND METHODS

### A. Study Site:

Soils were collected from Kerita farm (see Figure 1 for sampling sites) at a depth of 0 – 20 cm using a PVC pipe of approximately 1.5 cm diameter. The PVC pipe was inserted up to 20 cm into the soil at 12 different spots. The contents were emptied into plastic cylindrical containers of 250 g and labelled. Sampling from these maize growing farms was done with the aim of obtaining representative samples for the region. Two main types of soil samples were taken; soil from farmlands which have seen at least 20 years of fertilizer application and soil from virgin land from Kiptuimet Primary School with no fertilizer application was used as the control site. Fertilizer samples from frequently used brands in the region namely; Di-ammonium phosphate (DAP), Urea and Calcium of Ammonium nitrate (CAN) were purchased from the nearby Kolongolo market for macronutrients analysis. All samples were transported to the laboratories for preservation, storage and analysis. Prior to digestion, all the samples were air dried and crushed with a pestle and mortar, sieved through a mesh and kept in clean plastic containers.




(a) (b)

**Figure 1:** Location of Trans-Nzoia County in green (a) and Kerita farm sampling site (b) (*Not drawn to scale*)

### B. Sample preparation and analysis:

Total Nitrogen was analyzed by Kjeldahl method by Sherrif.[10] Approximately 0.1 gram of the soil samples were measured into a Kjeldahl digestion flask and 3 grams of Devarda's alloy was added to the samples to reduce the $NO_3^-$ into $NH_3$ under an alkaline condition. One tablet of Kjeldahl catalyst was added followed by 10 ml of $H_2SO_4$ before heating the sample in the digestion unit for two hours at 350 °C to fully convert any organic nitrogen in the sample into $(NH_4)_2SO_4$. Distilled water was added to the digested sample solutions and transferred into 50 ml volumetric flasks and made to volume. A 5 ml aliquot was pipetted from the 50 ml solution into a distillation flask and 10 ml of 40% sodium hydroxide (NaOH) was added to the solution. The $(NH_4)_2SO_4$ in the solution was converted to $NH_4OH$. 5ml of the resulting solution was distilled off into a receiving flask containing 5 ml of 2% boric acid ($H_3BO_3$) using methylene blue - methyl red indicator until the purple colour of the boric acid changed to blue.

The blue boric acid- ammonia solution was titrated against 0.01M HCl solution until the colour of the boric acid solution changed from back to purple. The volume was recorded and the process repeated one more time.

The mean titre was calculated and used to determine the total Kjeldahl nitrogen (TKN) as follows:

$$\% \text{ N} = \left\{ \frac{\text{N} \times \text{titre} \times 0.014 \times \text{volume of extract} \times 100}{\text{Weight of sample} \times \text{aliquot taken}} \right\}$$

Where N= molarity of HCl = 0.01; Volume of extract = 50 ml; Weight of sample = 0.1 grams; Aliquot taken = 5 ml; 1 ml of 0.01M HCl = 0.014 grams.

Phosphorous ($P_2O_5$) was determined using the UV-Visible Spectrophotometer.[10] Stock solution was prepared by diluting 140 ml of conc. $H_2SO_4$ with distilled water to 1 litre; 12 grams of ammonium molybdate were dissolved in distilled water to 250 ml in a 250 ml volumetric flask; 0.29 g of Antimony potassium nitrate was dissolved in 100 ml of distilled water; the three solutions were then mixed together and made to a volume of 2 litres solution with distilled water. 1.056 grams of Ascorbic acid were then dissolved in the 2 litre solution and mixed thoroughly. The sample (0.1 g) was weighed into a digestion tube, 20 ml of $HNO_3$ and 30 ml of perchloric acid added to the sample in a ratio of 1:1.5. The resulting mixture was heated in a microwave oven at a temperature of 350 °C for two hours and the digested sample allowed to cool and transferred to a 250 ml volumetric flask and made to volume with distilled water. An aliquot of 2 ml was taken from the 250 ml solution into a 50 ml volumetric flask and 10 ml of distilled water added. A drop of paranitrophenol solution was added and drops of $NH_3$ solution added until the solution turn yellow; at this point a neutralization point had been reached. 8 ml of stock solution was added for color development which was read with a UV/visible spectrophotometer. Blank and standard samples were prepared in the same way as the samples except that the blank did not contain the analyte of interest. The reading from the blank was used to eliminate background readings. The percent phosphorous (P) was calculated as follows:

$$\% \text{ P} = \left\{ \frac{\text{Reading} \times \text{volume of extract} \times 100}{\text{Weight of sample} \times \text{aliquot} \times 10^6} \right\}$$

The above calculation gives the concentration of the phosphorous in its elemental form. In order to determine the value of phosphorous as $P_2O_5$, a value of 2.3 was used as the conversion factor.[11]

$$\% \text{ P}_2\text{O}_5 = \left\{ \frac{\text{Reading} \times \text{volume of extract} \times 100}{\text{Weight of sample} \times \text{aliquot} \times 10^6} \right\} \text{x } 2.3$$

Where Volume of extract = 250 ml; Aliquot= 2 ml; Weight of sample = 0.1gram; Reading = reading from the UV/Visible spectrophotometer.

Potassium ($K_2O$) in soil samples was done using the flame photometer.[10] A sample (0.1 g) was weighed into a digestion tube. 20 ml of conc. $HNO_3$ to oxidize all the oxidizable matter in the sample and 30 ml of perchloric acid added to the sample. The sample was then covered and heated in the oven for up to 2 hours at a high temperature. The solution was cooled after digestion and transferred into 250 ml volumetric flask and made up to volume with distilled water. A potassium standard and blank solution was prepared in the same way. The solutions were taken to the flame photometer for reading which were used to calculate the percent $K_2O$ in the sample through the equation:

$$\% \text{ K} = \frac{\text{Reading} \times \text{volume of extract} \times 100}{\text{Weight of sample} \times 10^6}$$

The above calculation gives the concentration of potassium in its elemental K form. In order to calculate potassium in the oxide $K_2O$ form, a conversion factor of 1.2 was used.[11] Thus final expression is given as:

$$\% \text{ K}_2\text{O} = \left\{ \frac{\text{Reading} \times \text{volume of extract} \times 100}{\text{Weight of sample} \times 10^6} \right\} \text{ x } 1.2$$

## II. RESULTS AND DISCUSSIONS

**A. General soil characteristics:**

Farm soils were characterized based on four different texture classes namely Sandy Clay Loam, Sandy Clay, Silty Clay loam and Clay. The percentages of particle size composition are shown in Table 1 below. All the four different textural soil classes were observed in Kerita maize farm soils while the control site had only Sandy Clay soil type. The pH of the farm soils was characteristically lower than the control sites suggesting potential effect of fertilizers on farm soil acidification. Consequently, enhancing leaching of the macronutrients from area agricultural soils. There was no correlation between soil texture and soil pH.

**Table 1.** Soil texture characteristics of Kerita and control site

| Site | Soil properties | | | | |
|---|---|---|---|---|---|
| | **pH** | **% Sand** | **% Clay** | **% Silt** | **Texture Class** |
| FAS1 | 4.88 | 64 | 26 | 10 | Sandy Clay Loam |
| FAS2 | 5.00 | 59 | 32 | 9 | Sandy Clay Loam |
| FAS3 | 4.94 | 50 | 46 | 4 | Sandy Clay |
| FAS4 | 5.38 | 48 | 44 | 8 | Sandy Clay |
| FAS5 | 5.54 | 33 | 47 | 20 | Clay |
| FAS6 | 4.74 | 30 | 51 | 19 | Clay |
| FAS7 | 4.94 | 12 | 36 | 52 | Silty Clay Loam |
| FAS8 | 4.78 | 29 | 42 | 29 | Clay |
| FAS9 | 5.14 | 36 | 45 | 19 | Clay |
| FAS10 | 5.24 | 39 | 53 | 8 | Sandy Clay |
| FAS11 | 4.84 | 62 | 24 | 14 | Sandy Clay Loam |
| FAS12 | 5.04 | 54 | 21 | 25 | Sandy Clay Loam |
| CS1 | 6.20 | 50 | 46 | 4 | Sandy Clay |
| CS2 | 6.50 | 39 | 55 | 6 | Sandy Clay |

## B. Concentration of macronutrients in soils:

Concentration of phosphorous in the maize farm soil ranged from 35 ppm to 44 ppm with the highest concentration of 44 ppm at FAS4 and the lowest concentration of 35 ppm at FAS5. However, the concentration of phosphorous level in the control site was at 15 ppm. Whereas the amounts of phosphorous required vary from plant to plant.[8] The 35 ppm-44 ppm range is regarded as adequate phosphorous levels in for maize growth (Table 2). The significant difference of phosphate between the farm soils and the control sites was attributed to phosphate fertilizers that have been applied to maize farm soil for more than 20 years. The high levels of phosphorus in the soil could be associated with the increased use of phosphate fertilizers. However, the effect of the fertilizers on soil phosphorous varied from one site to another. Once phosphorous is built to a good level after fertilizer application, it would remain for many years without any additional phosphorous input. The reason is that phosphorous is less soluble in water and leaching is minimal.[12] It is estimated that as much as 90% of added phosphorus is fixed in soils[13] and made unavailable to plants. A significant increase in soil phosphorous was observed when measured before and after crop harvest.[8] The fact that annual addition of phosphorus causes its buildup in the soil could explain why the concentration of phosphorous was higher in maize farm soils compared to the control site.

**Table 2:** N, P and K concentrations (mean ± SD mg kg-1 of dry weight) in soil samples from Kerita farm and the control site

| Site | P (ppm) | %K | %N |
|---|---|---|---|
| FAS1 | 40 | 0.6 | 0.12 |
| FAS2 | 36 | 0.42 | 0.1 |
| FAS3 | 41 | 0.55 | 0.1 |
| FAS4 | 44 | 0.64 | 0.11 |
| FAS5 | 35 | 0.48 | 0.1 |
| FAS6 | 38 | 0.59 | 0.12 |
| FAS7 | 42 | 0.44 | 0.1 |
| FAS8 | 35 | 0.65 | 0.12 |
| FAS9 | 39 | 0.51 | 0.11 |
| FAS10 | 40 | 0.64 | 0.11 |
| FAS11 | 39 | 0.52 | 0.11 |
| FAS12 | 43 | 0.48 | 0.11 |
| CS1 | 15 | 1.16 | 0.12 |
| CS2 | 15 | 1.14 | 0.12 |
| Mean (FAS) | 39.33±2.96 | 0.54±0.08 | 0.109±0.01 |
| Mean (CS) | 15.00±0.00 | 1.15±0.01 | 0.12±0.00 |

Total Nitrogen in the farm soil ranged from 0.11% to 0.12% while in the control site the total nitrogen was 0.12% with mean concentrations of 0.109±0.01 and 0.12±0.00 for the farm soils and the control site, respectively, implying lower total nitrogen in farm soil compared to the control site (Table 2). Total nitrogen in the Kerita farm soil was regarded as low since it was within the range of 0.05%-0.11% for maize production.[14] Values from the control soil samples were regarded as normal since they were within 0.12%-0.25%. Compared to other studies conducted elsewhere,[15,16] obtained similar results with higher Total Nitrogen contents in the uncultivated farmlands compared to the levels in the farmland, and concluded that Total nitrogen contents could be expected to increase significantly after the farmland had been abandoned for ten years and that application of inorganic fertilizer alone is not sufficient to maintain level of nutrients under conditions of conventional management in which no above ground crop residues are returned to the soil.

Potassium in farm soils ranged from 0.42% to 0.65%, while in the control site the concentration was between 1.14% and 1.16% (Table 2). Maize farm had lower mean concentration of K at 0.54±0.08% as compared to the control site that had a mean concentration of 1.15±0.14%. The difference was in agreement with earlier studies,[17,18,19] which showed that intensively cropped soils developed potassium deficiency, in contrast to an old belief that soils in Kenya have sufficient amounts of potassium and would not benefit from potassium fertilizers.[20,21] Figure 2 shows the comparison of the levels of macronutrients in Kerita maize farm and the control site.

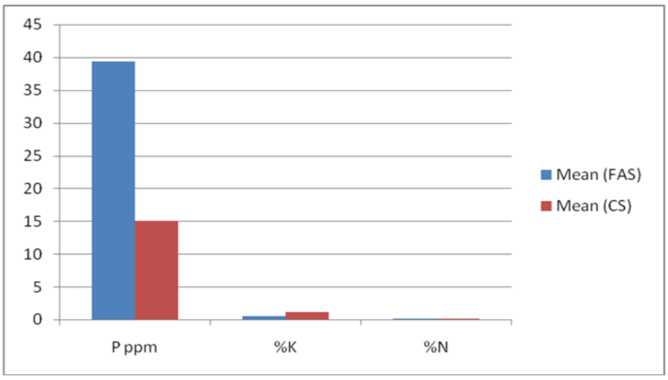



**Figure 2.** Comparison of N, P, K in Maize farm soils with the control site

**C. Macronutrients in major fertilizers used in Kerita farm:**

The major fertilizers used in Kerita farm were identified as Di-ammonium Phosphate (DAP), Urea and Calcium of Ammonium Nitrate (CAN). The results of analysis to ascertain the content of macronutrients are summarized in Table 3.

**Table 3.** Macronutrient content in major fertilizers used in Kerita farm

| Fertilizer | % $P_2O_5$ | | %K | | %N | |
|---|---|---|---|---|---|---|
| | Observed | Expected | Observed | Expected | Observed | Expected |
| UREA | 0 | - | 0 | 0 | 43.8 | 46 |
| CAN | 0 | - | 0 | 0 | 16.5 | 26 |
| DAP | 66.7 | 46 – 54 | 0 | 0 | 20.3 | 18 – 21 |

Most of the primary macronutrients were not in agreement with labelled contents reported by producers despite the regulation requiring product registration and/or licensing to assure the correctness of the declared concentrations as per the label on the fertilizers. The DAP fertilizer selected had a label of 18–46–0 fertilizer grade which was supposed to contain, by weight, 18% nitrogen (N), 46% phosphorus (P), and 0% potassium (K). However phosphorus content was 66.7% which was higher than the DAP fertilizer composition of 46% - 54%. Nitrogen content in DAP fertilizer sample of 20.3% was within the standard requirement for fertilizers composition of 18% - 21% and Potassium content in DAP fertilizer met the recommended requirement composition of 0%. On the other hand Urea fertilizer had 43.8%N which was below the minimum standard requirement of 46%N. Nitrogen content in CAN fertilizer sample was 16.5%, which was below the minimum requirement of 26%N. The findings of concentrations of major elements in this study are in agreement with which also observed discrepancies in NPK fertilizers than labelled contents.[22]

## III. CONCLUSIONS

Phosphorus levels in maize farm soil were regarded as adequate for maize growth since they ranged between 35 ppm and 44 ppm. Nitrogen levels in farm soil was low since concentrations between 0.05%-0.11 % were below 0.12 % which is regarded normal for maize production Potassium was deficient in the soil compared to the recommended levels for maize production. The results suggest that overdependence on chemical fertilizers is contributing to imbalances in the concentrations of nitrogen and potassium in Karita soil. Therefore, application of organic manure combined with inorganic fertilizers is recommended to improve the soil nitrogen, phosphorus, and potassium nutrients balance.

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