

Original Research Article

Fertility Status of Soils of Morogoro District, and Response of Maize to Applied N , P and S.

ABSTRACT

Information on soil fertility is very important on application of fertilizers as plant nutrients supplements to the deficient nutrients in the soil. This study objectives was to evaluate the current fertility status of soils of Morogoro District and re-establish the optimum rates of Nitrogen, Phosphorus and sulphur. Two field experiments were carried out in a season 2015/2016. Eighteen maize growing areas were selected, top soils, composite samples from a depth of 0-20 cm was collected and analyzed for physical and chemical properties as per standard procedures in the laboratory. Soil analysis laboratory results used as a means for soil fertility status rating. Two of those sites (Kiziwa and Fulwe) with P, N and S variability were used for field experiments. Treatments for field experiment were varied fertilizer levels, namely 0, 50, 100 kg N ha⁻¹, 0,10, 20 kg Pha⁻¹ and 0,10, 20 kg S ha⁻¹. Absolute control treatment was included in both experimental site and the experiments was arranged in a completely randomized block design with three replicates at both sites. Results showed that studied soils had low soil fertility with slightly acidic to neutral pH in water (6.6-7.5), Low organic carbon (0.7-1.3%), low to very low total N (<0.01) and low extractable S (<3 mg/kg). 28% of studied soils had very high levels of P, low to very low CEC, very high exchangeable Ca²⁺, Mg²⁺ very low Na⁺ and adequate levels of K with micronutrients not limiting. Grain yield was significantly increased with application of N, P and S at (P=0.05). Therefore a tentative nutrient combination of 50-100 kg N ha⁻¹, 10-20 kg P ha⁻¹, and 10-20 kg S ha⁻¹ may be the best strategy for improving maize yields in Morogoro District while monitoring P Levels with time.

Keywords: Soil fertility evaluation, maize, fertilizer levels, yield response

1. INTRODUCTION

Maize is a cereal crop consumed as a staple food by over 80% of Tanzanians [1]. According to [2] the national average per capita consumption is 113 kg per year; and the national average maize yield is 1.69 t ha⁻¹ while the potential is 4.0 t ha⁻¹. Maize production trend in Tanzania has been fluctuating. Maize production was reported to be 3 302 000, 3 555 000 and 3 324 000 tonnes in 2007, 2008 and 2009 respectively [3]. Furthermore, in 2008/09 national food production for maize was 3 424 984 tonnes while the requirement was 4 131 782 tones resulting into a deficit of 706 797 tones. This is because soils of the cultivated fields are highly weathered [4], and are subjected to intensive and continuous cultivation with low levels or without fertilizer application [1,4 and 6]. Soil analysis results reported by Nickson, [5] shows low total N (< 0.1) and low P (< 5 mg kg⁻¹) in some villages (Mkambarani, Changa, Ngerengere, Sinyaulime and Maseyu) of Morogoro District. Similarly zinc (Zn) and boron (B) have been reported to be deficient in 38% of soils from Kilombero and Wami valleys, Morogoro region [6]. Furthermore [7] reported that, Morogoro soils have low total N (0.09 to 0.1) and 40% of the district having low, P < 6.50 mg kg⁻¹ soil which implies about 40% of the region should be

included in the N and P fertilizer regime for optimum maize yield. Few maize farmers use inorganic fertilizers in Morogoro district and for those using fertilizers, nitrogen is the common nutrient applied. About four percent of rice producers in Morogoro District [1] apply fertilizers containing nutrients like phosphorus (P), potassium (K), sulphur (S), zinc (Zn) as a result these nutrients are gradually declining in soils. On the other hand, S is also lost from soils through leaching, burning and crop uptake. Apart from 1 kg S and 40 g Zn lost per hectare through producing one tone grain of the high-yielding rice variety [6], other nutrients like 22 kg N, 3.1 kg P, 28 kg K are also exported from the soil. A recent study [7] supports the hypothesis that S and Zn are low and emerging as limiting factors for rice production in soils of Morogoro. Similarly, another study [5] found 40 % and 10 % of soil samples taken from five maize-producing areas in Morogoro district had low levels of S and Zn, respectively. A recent researcher [8] found all (100 %) of the twenty soil samples sampled in Morogoro maize production areas were N deficient while 29 % were deficient in P. This suggests that application of S and P and N fertilizers is indispensable to optimize maize yields.--.

The only fertilizer recommendations existing in Morogoro Region for maize production is that of 1993 basically for N and P. As per [8], the fertilizer recommendation for maize production is 40 kg N ha^{-1} and 20 kg P ha^{-1} for Dakawa, Ilonga and Gairo. It can be concluded that, despite of the importance of fertilizer rates which adds the deficit nutrients in the soil there is neither current recommendation for N, P and S. Therefore the objectives of this study was (i) To determine the fertility status of soils in selected sites of Morogoro District (ii) To determine the response of maize to application of selected limiting nutrients (N, P and S).

2. METHODOLOGY

Two field experiments were set to study the response of maize to N, P and S by applying different levels of Nitrogen, phosphorus and sulphur in a season 2015/2016. The experimental sites were located at Kiziwa (060 46' 49.6" E / 0370 51' 21.6" S) and Fulwe (060 46' 06.9" E/ 0370 52' 31" S) in Morogoro District. Maize (*Zea mays* L) variety TMV used as a test crop. Eighteen farms famous in maize cultivation were selected and composite soil samples from a depth of 0-20 cm were sampled and analyzed for physical and chemical properties in the laboratory.

The experimental areas receives an annual rainfall ranging between 1200 and 1500 mm and the temperature ranges between 26 to 32 °C. Within Morogoro District, 18 villages famous in maize

production were selected and surveyed. Soil samples were collected from maize growing farms at a depth of 0-20 cm for analysis in the laboratory. After analysis two sites with varied levels of Nitrogen, phosphorus and sulphur were selected and used for the field experiment. Two experiments were set at two different villages, both evaluating the performance of different rates of N, P and S. Treatments for both experiments contained varied levels of N, P and S. Treatments for the field experiment applied were Nitrogen at a rate of 0, 50 100 kg ha⁻¹, phosphorus 0,10 20 kg ha⁻¹ and S 0, 10 and 20 kg ha⁻¹ both experiment had an absolute control plot with no any nutrient applied. The experimental units were arranged in a completely randomized block design with three replicates at both field sites (Kiziwa and Fulwe). Other essential nutrients (i.e. N, S, Mg, Ca and Zn) were applied to avoid untargeted nutrients to limit the response of maize to P K and S. Nitrogen was applied as Urea, K as Muriate of potash (60 % K₂O), Di-ammonium phosphate as a source of N and P, Ammonium Sulphate (21% N) as a source of S (24%) and part of N, Zinc sulphate (34%) and Zinc chloride as sources of Zn. All nutrients were applied at planting except 60% N and S which was applied at 21 days after planting.

Three to four maize seeds (TMV1) was planted at 30 cm × 60 cm. At 12 days after planting the seedlings were thinned to two plants per hill. The dose of N and S were top dressed to all treatments at 21 days after planting. All other agronomic practices for managing a maize field were observed. At maturity the crop was harvested from a plot of 4 m × 3.5 m, leaving the first guard row surrounding the plot. Three rows with two plants per hole were harvested. Maize cobs were dried, then shelled and then maize grains were dried to around 12-15% moisture content. Dry maize grain were weighed from each harvested area and the results were presented in tones per hector.

2.1 Laboratory soil test

Approximately one kilogram soil sample collected from 18 maize growing villages were analyzed at Sokoine university of Agriculture at the department soil and geological science. Particle size distribution was determined by hydrometer method after dispersing the soil particles by 5% sodium hexametaphosphate [9] and textural classes were determined by using the USDA textural triangle [10] Soil pH was measured potentiometrically in water at a ratio of 1:2.5 soil–water [11]. Basic cations (Ca, Mg, K and Na) from ammonium acetate (NH₄OAc) leachate [12]. The total exchangeable bases (TEB) were calculated arithmetically as a sum of four exchangeable bases (Ca²⁺, Mg²⁺, K⁺ and Na⁺).

Available Micronutrients were determined by Diethylene triamine penta acetic acid (DTPA) method and their respective concentration in the filtrate were determined by atomic absorption spectroscopy using appropriate standards [13]. Extractable sulphur was extracted by Calcium orthophosphate method [14]. The Organic carbon content of the soils was determined by chromic acid wet digestion method [15].

2.2 Data Analysis

All the data collected, nutrient concentration in soils, grain response to N, P and S were subjected to analysis of variance using GenStat Discovery Edition 4. Means were compared by Duncan multiple range test (DMRT) at $P = 0.05$. The coefficient of variation (CV) in percentage was recorded.

3. RESULTS AND DISCUSSION

3.1 Fertility Status of Morogoro District

3.1.1 Particle size distribution

Particle size distribution data are presented in Table 1. The average soil texture was sandy clay loam, clayey to sandy loam, however particle size distribution varied widely. [10] reported that soils with more than 65% sand and less than 18% clay frequently have low fertility status. Therefore soils of Fulwe, Changa, Kikundi, Gozo, Pangawe, Kibangire, Mkambarani, Maseyu, and Kiziwa are likely to have inadequate soil fertility. Soil texture is the composite of coarse fraction (sand) and the finer fraction (silt and clay) and any alteration in one component affects the other component therefore affecting the physico-chemical properties of the soils [10].

Table 1: Physical properties of representative top soils in Morogoro District (0-20 cm)

Site	Clay (%)	Silt (%)	Sand (%)	USDA textural classes
Kingolwira	48.8	8.9	42.2	Clay
Mkambarani	20.8	8.9	70.2	Sandy clay loam
Lubungo	20.8	6.9	72.2	Sandy clay loam
Mlali	16.8	8.9	74.2	Sandy loam
Kiroka	20.8	6.9	72.2	Sandy clay loam
Mkonowa Mara	28.8	20.9	50.2	Sandy clay loam

Bigwa	24.8	10.9	64.2	Sandy clay loam
Kibangire	14.8	10.9	74.2	Sandy loam
Kiziwa 1	18.8	8.9	72.2	Sandy loam
Kiziwa 2	20.8	12.9	66.2	Sandy clay loam
Maseyu	12.8	10.9	76.2	Sandy loam
Pangawe	20.8	12.9	66.2	Sandy clay loam
Kibangire	34.8	16.9	48.2	Sandy clay loam
Gozo	16.8	10.9	72.2	Sandy loam
Kikundi 1	14.8	6.9	78.2	Sandy loam
Kikundi 2	18.8	4.9	76.2	Sandy loam
Fulwe	14.8	4.9	80.2	Sandy loam
Changa	10.8	6.9	82.2	Loamy sand

3.1.2 Chemical Properties

Some soil chemical properties of the studied soils are presented in Table 2 . Surface soils studied were generally slightly acidic to neutral (6.6 - 7.5). [13] suggested that pH of dry soils ranging from 5.5 to 6.5 is satisfactory for production of a variety of crops. This pH range favours availability of plant nutrients like N, P, K,S, Ca, Mg, Bo, Cu, Fe and Zn [13].

Table 2. Some chemical properties of representative top soils from selected sites of Morogoro District

Location	pH _{H2O}	Total N(%)	P (mg/kg)	S (mg/kg)	OC(%)	CEC (cmol (+) /kg)
Kingolwira	6.2	0.14	6.4	0.44	1.3	16
Mkambarani	6.7	0.20	5.6	0.24	0.7	20.9
Lubungo	6.9	0.14	28.9	0.3	0.7	13.3
Mlali	6.5	0.14	28.9	0.49	0.6	15.4
Kiloka	6.1	0.14	28.3	0.34	1.3	13.7
Mkonowa Mara	6.8	0.20	30.3	0.54	1.3	24.1
Bigwa	7.2	0.14	13.7	0.34	0.6	6.9
Kibangire	6.5	0.13	42.1	0.23	1.3	9.3
Kiziwa 1	6.5	0.19	9.6	0.45	1.3	10.7
Kiziwa 2	6.7	0.13	6.4	0.5	1.3	11.3
Maseyu	6.8	0.14	4.8	0.34	1.3	19.8
Pangawe	7.5	0.16	19.1	0.51	0.6	14.7
Kibangire	6.4	0.20	29.3	0.35	0.7	4.8
Gozo	7.2	0.15	9.7	0.19	1.3	13.7
Kikundi 1	6.8	0.14	8.4	0.26	1.3	14.7
Kikundi 2	6.4	0.09	5.6	0.33	1.3	14.1
Fulwe	6.5	0.15	9.2	0.31	1.3	5.9

Changa	7.1	0.10	41.4	0.23	1.3	8.2
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115
116 Organic carbon varied from 0.7 % to 1.3 %. According to [16] the studied soils had low organic carbon
117 contents (0.7-1.3%). Other results [11 and 17] indicated soils from these areas are characterised by
118 low organic carbon contents. It has been established that N availability for plants uptake is positively
119 correlated with the ~~quantity~~, quality and decomposition of organic matter in soils. Therefore
120 application of N to these soils is advised for optimum maize production in soils of Morogoro District.
121 Soils with low OC are known to contain low to very low total nitrogen and other plant nutrients.
122 Generally low values of OC in the study may be attributed to low accumulation and rapid
123 decomposition of plant residues into the soil every season[13].
124
125 Total N levels varied from 0.09 to 0.2%. Based on guidelines compiled by Msanya [15], ~~Of~~ of the soils
126 tested, Mkono-wa mara and Fulwe had low total N (0.15% and 0.2% respectively) while the rest had
127 very low total N (<0.1%). According to [2], the quantity of nitrogen is closely related to the amount of
128 soil organic matter which makes approximately 5% of soil volume. These results indicated that all the
129 soils tested had very low to low level of total N levels implying inability of the soil to supply adequate N
130 for plant growth. This means that nitrogen fertilizers have to be applied each time when maize
131 cultivation is done and this is especially evident in all tested soils.
132
133 The levels of Bray-I extractable P for soils of some sites [13] were observed to be above critical
134 values. The high values extended from 28.9 mg/kg to 42.1 mg/kg as adequate for maize production
135 for soils of Lubungo, Mlali, Kiroka, Changa and Kibangire. This was contrary to (38.9%) which had
136 relatively low extractable P ranging from 4.7 mg/kg to 9.7 mg/kg suggesting inadequate P for maize
137 production in the particular locations. This means that over 30% of the soils in Morogoro district have
138 low levels of P and require P application for optimum maize production. The results by [16], supports
139 this findings, and low P results of this research is thought to be associated with continued land use
140 and soil fertility deterioration.
141
142 Sulphur in the studied soils varied from 0.2 to 0.5 mg/kg. according to [13] soils of Morogoro District
143 had low extractable S. Similarly low levels of S were obtained in soils of Kibena tea Estates. Results
144 indicates that all the soils tested in Morogoro District require application of S for optimum maize

production. According to [13], S enhances P uptake by plants and calcium can cause S precipitation and therefore, reducing S availability to plant. Retaining plant residues into fields and addition of S containing fertilizers will help to manage S problem in these areas.

3.2.1 Exchangeable bases

Levels of determined exchangeable bases (Ca, Mg, Na, and Na) in top soils of representative maize growing villages is presented in Table 3.

Table 3: Levels of exchangeable bases of top soils from 18 sites in Morogoro District

Location	Exchangeable Bases cmol(+)/kg			
	Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺
Kingolwira	0.6	3.1	3.2	0.48
Mkambarani	1.1	3.8	1.9	0.13
Lubungo	1.4	2.4	1.8	0.09
Mlali	13.9	2.1	1.3	0.52
Kiroka	1.4	2.2	0.8	0.07
Mkonowa Mara	1.1	2.8	0.6	0.17
Bigwa	3.4	1.5	2.5	0.58
Kibangire	1.3	1.6	0.9	0.17
Kiziwa 1	6.1	2.1	0.9	0.09
Kiziwa 2	9.4	6.3	1.9	0.07
Maseyu	5.7	2.7	0.7	0.11
Pangawe	8.9	1.8	2.3	0.64
Kibangire	4.8	2.3	0.6	0.09
Gozo	5.3	1.3	1.1	0.09
Kikundi 1	7.8	6.3	1.5	0.11
Kikundi2	8.1	5.1	0.5	0.07
Fulwe	3.5	2.2	1.1	0.11
Changa	5.7	2.7	0.4	0.04

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Calcium

Calcium levels in tested soils ranged between 0.6 to 9.413.9 cmol (+) kg⁻¹(Table 3). According to [18] soils of Kingolwira, Mkambarani, Lubungo, Kiroka, Mkono wa Mara, Bigwa and Kibangire with textural class of sandy clay loam, had Ca²⁺ values ranging from 0.6 cmol (+) kg⁻¹ to 3.1 cmol (+) kg⁻¹ being rated as very low to medium, the rest had calcium values ranging from 4.8 cmol (+) kg⁻¹to 9.4 cmol (+) kg⁻¹, loamy soils being rated high. [19] suggested that maximum maize growth occurs when Ca²⁺ saturation is about 8- 20% of the CEC. Levels of Ca for soils of Mlali, Pangawe, Kikundi and Kiziwa

was within the range [s](#), while the rest of the soils were below this range, implying possibility of Ca^{2+} deficiency to maize grown in those areas.

Potassium

Exchangeable K^+ for the studied soils of Morogoro district varied from 0.6 to [3.1-2](#) $\text{cmol}(+) \text{kg}^{-1}$. According to guidelines by [19], soils of Kiroka, Mkono wa Mara, Maseyu, Kikundi, Changa, Bigwa and Kibangire, with textural class of sandy loam had extractable K ranging from 0.4 - 0.9 $\text{cmol}(+) \text{kg}^{-1}$ which was rated as high. The rest of tested soils had K^+ values above the critical values. These results indicated that all the soils tested in Morogoro District had adequate levels K. [13] suggested that K deficiency may appear when K is very low in soils and when it drops below 2% of the CEC.

Magnesium

Magnesium levels ranged from 1.3 to 6.3 $\text{cmol}(+) \text{kg}^{-1}$ Table 5. Agricultural soils of Morogoro district had high levels of extractable Mg (1.3 - 6.3 $\text{cmol}(+) \text{kg}^{-1}$). According to [13] deficiency of magnesium may appear when exchangeable Mg drops below 3 -4%, hence the studied soils had adequate Mg for maize production. Levels of extractable Na varied from 0.07 -0.64 $\text{cmol}(+) \text{kg}^{-1}$. Of the soils tested, soils of Kingolwira, Mlali, Bigwa, and Pangawe had Na values from 0.4 to 0.6 $\text{cmol}(+) \text{kg}^{-1}$. Based on Guidelines complied by [19] Na values are rated as medium. The rest had very low to low levels (0.1 - 0.3 $\text{cmol}(+) \text{kg}^{-1}$). This suggests that levels of Na in Morogoro soils will provide conducive environment for maize production. [5] documented that when high percent of the CEC is occupied by Na, soil structure is destroyed by dispersing soil aggregated leading soils impermeable to water, the situation becomes even more serious in clay soils.

3.2.2 Levels of extractable micronutrients

Micronutrients determined were Copper, Zinc, Manganese and Iron (Table 4). According to [13 and 19), the critical range of copper is 0.1 to 0.25 mg Cu /kg. Levels of Cu found in the 18 soils were all above the critical range hence the soils tested had adequate levels of Cu. Overall results indicate that agricultural soils of some parts of Morogoro District would supply adequate Cu for optimum growth of crops.

The critical range of Zn in soils [13 and 18] is 0.2 to 2.0 mg Zn /kg. Of the studied soils, soils of Fulwe, Kibangire and Maseyu had relatively low values of Zn falling on the lower limit of the critical range. These indicated that these areas are Zn deficient. However, the findings portray the rest of the soils tested have adequate levels of Zn for optimum production of crops.

The critical range for iron is 2.5 to 5.0 mg /kg and 1.0 to 5.0 mg /kg for manganese [13 and 20]. It was documented by [13] that Mn is rated as high when more than 2000 mg /kg are found in soil. Therefore the levels of Mn in the current study were to not limiting and not to toxic in the soils tested.

Table 4: Levels of extractable micronutrients of representative agricultural soils in Morogoro District

Location	Micronutrients (mg/kg)			
	Cu	Zn	Mn	Fe
Kingolwira	1.21	1.17	97.4	42.2
Mkambarani	0.8	0.9	52.9	67.2
Lubungo	1.6	2.3	52.9	70.1
Mlali	0.6	2.7	40.2	78.9
Kiloka	1.8	4.4	41.8	94.4
Mkonowa Mara	0.4	3.6	106.9	122.2
Bigwa	1.3	1.1	26.7	13.3
Kibangire	1.1	2.8	48.1	78.9
Kiziwa 1	1.1	0.7	48.2	34.4
Kiziwa 2	1.3	3.7	60.8	46.7
Maseyu	0.8	0.3	32.3	77.8
Pangawe	1.1	0.7	33.9	11.1
Kibangire	1.3	0.3	40.2	31.1
Gozo	0.8	0.8	34.7	18.9
Kikundi 1	0.5	1.1	46.6	35.6
Kikundi 2	0.5	0.5	32.3	66.7
Fulwe	0.4	0.2	29.3	2.2
Changa	0.5	3.7	92.6	35.1

Table 5. Initial Status of plant nutrient at the experimental sites

Particulars	Kiziwa	Fulwe	Method
%Sand	66.2	80.2	Hydrometer method
%silt	12.0	4.0	
%clay	20.8	15.8	
pH	6.7	6.5	pH Meter
N(%)	0.13	0.15	
OC(%)	1.3	9.2	Glass Electrode pH Meter
P (mg/kg)	6.4	0.3	
S(mg/kg)	0.5	1.3	Bray -1
CEC	11.3	5.9	
Ca	9.4	3.5	
Mg	6.3	2.2	
K	1.9	1.1	
Na	0.07	0.11	
Cu	1.3	0.4	
Zn	3.7	0.7	
Mn	60.8	29.3	
Fe	46.7	22	

3.4.1 Grain Yields as Affected by N, P and S at Kiziwa and Mikese Field Trials

3.4.1.1 Response of N application on maize grain yield at Kiziwa and Mikese

Grain weight per plot was significantly affected by application of N Table 6. Maize crop fertilized at the rate of 50 and 100 kg N produced maximum grain yield of 5.7 and 5.2 tonnes at Mikese and Fulwe respectively which was statistically significantly ($P = .05$), from the control plot. Highest grain yield was recorded at the rate of 100 kg N at Fulwe and Kiziwa. The increase in grain yield by increase in N levels is thought be due to increase in grain number per cob, more grains per row and cob length. The increase in grain weight at tasselling due to increase in N application is ascribed to its positive effects on plant height, stem diameter and leaf number per plant, enhanced crop growth rate and net assimilation rate which ultimately increased the grain yield [14]. Higher grain yield with nitrogen application was also reported by [20, 14 and 21]. Following this study nitrogen rates of 50 kg N at Fulwe and 100 kg N at Kiziwa should be applied in maize production in order to optimize maize yield [There is no evidence to prove this sentence. Please explain.](#)

3.4.1.2. Response of Sulphur application on maize grain yield at Kiziwa and Mikese

Maize yield increased with Sulphur application at both experimental sites.(Table 6). Grain yield increased with S application from 2.7 and 1.4 tonnes at Fulwe and Kiziwa control plots to maximum grain yield of 7.9 and 5.2 tonnes in treatment plots where S was applied at 20 kg S ha⁻¹ plus all other limiting nutrients. Both experimental sites had statistically significant yield increases to applied S .This increase in grain yield by the application of S is associated with requirement for disulphide bond formation between polypeptide chains. Sulphur is required for the synthesis of various metabolites example Co-enzyme A which is involved in the oxidation and synthesis of fatty acids [5]. These results are in conformity to those reported by [17].

3.4.1.3 Effects of P rates on maize grain yield in Fulwe and Kiziwa sites

The effects of P fertilizer rates on maize grain yield at Fulwe and Kiziwa sites are presented in Table 6. All fertilizer treatments produced significantly higher grain yield than the absolute control. Grain yield increased with P application up to 6.4 tonnes at Fulwe and 5.0 tonnes at Kiziwa. Differences in grain yield response of maize at the two sites were significant at $P=.05$. These results indicate that soils across the study sites were deficient in nutrients especially P (Table 6) and that fertilizer application is crucial for maize production. These results are close to those reported by [7] who revealed highest grain yield when 30 kg P ha⁻¹ with other plant nutrients taken into account (B, Mo, Zn, Mn and S) were applied. This affirms that nutrient balance plays a significant role in increasing crop production and its quality. For the major processes of plant development and yield formation, the

235 presence of nutrients like N, P, K, S, Mg and Zn at balanced levels and good crop husbandry
236 practices is essential [14 and 22] .

237 **Table :6 Grain yields at treatment effect on maize yeld at Fulwe and Kiziwa**

Treatment	Mikeese-Fulwe (t/ha)	Kiziwa (t/ha)
N ₀ P ₀ K ₀ S ₀ ZN ₀	2.7a	1.4a
N ₀ P ₂₀ K ₅₀ S ₂₀ ZN ₁₀	3.5abc	1.8a
N ₅₀ P ₂₀ K ₅₀ S ₂₀ ZN ₁₀	4.2abc	3.8 bc
N ₁₀₀ P ₂₀ K ₅₀ S ₂₀ ZN ₁₀	5.7cd	5.2 e
N ₁₀₀ P ₀ K ₅₀ S ₂₀ ZN ₁₀	4.1abc	3.8bc
N ₁₀₀ P ₁₀ K ₅₀ S ₂₀ ZN ₁₀	4.5bc	4.7cde
N ₁₀₀ P ₂₀ K ₅₀ S ₂₀ ZN ₁₀	6.4de	5.0 de
N ₁₀₀ P ₂₀ K ₅₀ S ₀ ZN ₁₀	3.2ab	3.9bcd
N ₁₀₀ P ₂₀ K ₅₀ S ₁₀ ZN ₁₀	5.1cd	5.2e
N ₁₀₀ P ₂₀ K ₅₀ S ₂₀ ZN ₁₀	7.9 e	5.2 e
CV (%)	19.8	6.6

238 Means bearing same letter(s)in the same column are not significantly different ($P=.05$) using Duncan's
239 Multiple Range test.

240
241
242 **4. CONCLUSION**

243 i. Based on data for topsoil samples, soils of the studied areas have low to medium soil
244 fertility, the major limiting nutrients were N, S and P while Zn was inadequate in 20 % of
245 the studied soils .

246 ii. From the two field experiments it was found that the optimum rates of N, S and P
247 were; 50-100 kg/ha, 10-20 kg/ha and 10-20 kg/ha respectively.

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