

Original Research Article

**OPTIMUM LEVELS OF SULPHUR AND ZINC FOR RICE
IN LOWLAND AREAS OF KILOMBERO DISTRICT,
TANZANIA**

ABSTRACT

Two on-farm farmer-researcher managed experiments were carried out from January to May of 2014 and 2015 at Mkula, Mbasa and Kisawasawa sites to establish optimum rates of sulphur (S) and zinc (Zn) for rice production in Kilombero district, Tanzania. The treatments tested were: an absolute control and a control for N in both of the experiments. The other treatments for S experiment were a control for S but containing adequate N and Zn; adequate levels of N and Zn plus sulphur rates of either 10 or 20 kg S ha⁻¹. In the second experiment comparable treatments were used but the nutrient under test was Zn. The Zn treatments were a control for Zn and adequate levels of N and S plus Zn rates of either 2.5 or 5.0 kg ha⁻¹. The test crop was rice variety SARO-5. The results indicated that S application increased grain yield (GY) by 1.8, 2.8 and 1.8 t ha⁻¹ at Mbasa, Mkula and Kisawasawa, respectively. The shoot S concentration increased from 0.13 to 0.29; 0.13 to 0.24 and 0.16 to 0.22 % at Mbasa, Mkula and Kisawasawa, respectively. Zinc application increased yield significantly only at Mbasa site by 2.8 t ha⁻¹ and shoot-Zn concentration from 11.5 to 27.0 mg kg⁻¹. The recommended optimum rate of sulphur at Mbasa and Kisawasawa was 10 kg S ha⁻¹ while 20 kg ha⁻¹ was recommended at Mkula site. For zinc, the optimum rate at Mbasa site was 2.5 kg Zn ha⁻¹. It was concluded that sulphur deficiency was an extensive soil fertility constraint limiting rice production while Zn deficiency was found only in a few soils of Kilombero district.

Keywords: Words: Optimum rates, field experiment, nutrient responses

1. INTRODUCTION

In Tanzania, rice (*Oryza sativa* L.) is the second widely cultivated cereal as staple and cash crop after maize. It is a major source of income, food and employment across the country, and particularly rural areas of Kilombero Valley in Tanzania. However, rice productivity is low and it is continuously declining in

Tanzania. Many research works mentioned rice productivity to be as low as 1.0 t ha^{-1} under lowlands - rainfed [1, 2]. Such yields are far below the potential of SARO-5 improved rice variety, which has recorded yields of more than 6.5 t ha^{-1} in experimental plots [3,4].

Soil is the main source of plant nutrients and supplies at least 14 mineral nutrients to plants, some of which are sulphur and zinc [5]. Nutrient balance is very important in rice production and blanket use of fertilizer adversely affects its production. Nutrients in soil whether naturally endowed or artificially maintained are major determinants of success or failure of a crop production system [6]. Declining soil and crop productivity is a major problem facing smallholder farmers in Kilombero valley, Tanzania [4,7] and this is caused by continuous cropping without addition of adequate external soil fertility inputs [1,8]. More recent studies have confirmed that sulphur deficiency is a major problem covering more than 80 % of soils in Kilombero valley [4, 9]. A recent screen house study [9] demonstrated that rice grown in soils containing extractable S concentrations $<10 \text{ mg kg}^{-1}$ responded to S application, advancing a need to be confirmed under field conditions for establishing optimum levels of S in rice fields of Kilombero valley. Previously other researchers reported critical values or ranges for S. Citing few, [10] reported an S soil critical range of $6\text{-}12 \text{ mg kg}^{-1}$ in soils for most crops. [11] reported S critical value of $< 5 \text{ mg kg}^{-1}$ using 0.05 M HCl extractant while [12] using different extractants reported critical levels of 9.7 and 17.8 mg kg^{-1} for CaCl_2 and NaHCO_3 , respectively.

Several studies have documented effects of S application on rice tissue concentration and grain yields. [9] reported that application of other nutrients excluding S in soils with less than 10 mg kg^{-1} led to low level of S in rice shoots (ranges 0.12 to 0.16%) and low grain yields. This might be attributed to the fact that S is a component of enzymes, proteins and vitamins essential for protein synthesis and about 90 % of plant S is present as a constituent of the amino acids [13]. Consequently, S enhances nitrogen utilization and chlorophyll formation as a result affects plant vigor, nutrient concentration and grain yields. [14] reported an application of 30 kg S ha^{-1} significantly increased rice yield over the control in S deficient soil in India. [6] reported that application of S and other limiting nutrients increased rice yield by 35.16% above the control, indicating that inclusion of S was beneficial in rice production.

Zinc is an important micronutrient for rice production because it is required in a large number of enzymes and plays an essential role in DNA transcription. In addition, Zn is either a metal constituent in many

enzymes or is a functional co-factor of number of enzymes reactions [5,11]. [15] reported ZnSO_4 application at a rate of 6 mg Zn kg^{-1} soil increased grain yield by 41 % over the control when applied in a soil with available Zn of 0.9 mg kg^{-1} . In the same study Zn application increased significantly rice shoot Zn concentration from 7.09 mg kg^{-1} (rated as low) to 18.84 mg kg^{-1} (rated as sufficient). [16] reported a significant increase in grain yield after application of 5 mg kg^{-1} in a pot experiment using a soil with 0.86 mg kg^{-1} . Likewise, [6] reported an increase in Zn concentration in rice shoots from 27.0 in the control to 40.0 mg kg^{-1} after supplementing Zn on top of other necessary nutrients.

Earlier studies by [4,9] reported zinc deficient soils in Kilombero to constitute about 30 % of the tested soils indicating that Zn deficiency is emerging as a problem for high rice yields. Only four percent of farmers in Kilombero district use inorganic fertilizers [1] yet about 75 % of farmers produce the high yielding improved variety TXD 306 (SARO -5) with a high demand of nutrients [7]. Therefore, in general application of S and Zn fertilizers is likely to improve rice productivity. However, optimum rates of S and Zn in rice fields of Kilombero have not been established. Therefore, the objectives of the study were (i) To determine the response of rice to S and Zn in the cultivated rice fields in Kilombero valley (ii) To establish optimum rates of S and Zn for rice in Kilombero valley.

2.0. METHODOLOGY

2.1. General Description of the Study Area

The study area comprised three sites namely: Mkula, Kisawasawa and Mbasa located in Kilombero district, Tanzania. The study was carried out in the three sites during two different seasons: January to May of 2014 and 2015. The sites elevation ranged between 266 and 318 meters above sea level. The specific coordinates of the sites are given in Table 1.

During the growing seasons, the temperature ranged between 29.0 and 33.8°C . Total annual rainfall recorded was 1138.1 mm in season one and 995.3 mm in season two with monthly rainfall peaks in March and April according to Kilombero Sugar Weather Station. Comparable rainfall and temperature data (rainfall between 1200 and 1400 mm falling between December to June and annual temperature ranges between 26 and 32°C in Kilombero valley) have been reported by [8].

2.2 Soil sampling and sample preparation

Soil samples were collected at a depth of 0 – 20 cm from representative sites in important rice producing areas of Kilombero district. In each site a minimum of 10 sub-samples using an auger were collected randomly in a relatively uniform area of about 0.5 ha. The soil sub-samples from each site were mixed thoroughly to constitute a representative composite sample, which was sent to SUA for laboratory analysis.

2.3 Soil Analysis

Soil pH was analyzed (1: 2.5 soil: water suspension) by using a pH meter [17] extractable P was determined according to the Bray 1 method [18] following colour development using molybdenum blue method [19]. Exchangeable cations (Ca, Mg, K and Na) were determined from ammonium acetate (NH_4OAc) leachate [20]. Zinc was determined by Diethylene-triamine-pentaacetic-acid (DTPA) method [21] and its concentration in the filtrate was determined by atomic absorption spectrophotometry using appropriate standards. Extractable sulphur was extracted by calcium orthophosphate and determined by BaCl_2 turbidity method [22].

2.4 Management of Field Experiment and Data Collection

2.4.1 Experimental design

Two field experiments were carried out in three sites namely, Mkula, Mbasa and Kisawasawa for 120 days. At Mkula site, one acre was demarcated after soil analysis, where half of it was used in the first season (January to June 2014). The remaining (adjacent) part used in the second season (January to June 2015). These fields are hereafter referred to as Mkula A and B. Mbasa site was used only during season one (December to June 2014) while Kisawasawa was used during the second season (January to June 2015).

The first experiment was carried out to assess rice response to sulphur and the second was to assess rice response to zinc. The treatments tested in the first experiment were: i) an absolute control, where no fertilizer was applied (T1), ii) a control for N but containing S and Zn (T2), iii) a control for S but containing adequate N and Zn (T3), iv) adequate levels of N and Zn plus a sulphur rate of 10 kg S ha^{-1} (T4) and v) adequate levels of N and Zn plus an S rate of 20 kg S ha^{-1} (T5). These treatments were designated as: T1= $\text{N}_0\text{S}_0\text{Zn}_0$, T2= $\text{N}_0\text{S}_{20}\text{Zn}_5$, T3= $\text{N}_{100}\text{S}_0\text{Zn}_5$, T4= $\text{N}_{100}\text{S}_{10}\text{Zn}_5$, and T5= $\text{N}_{100}\text{S}_{20}\text{Zn}_5$. In the second

95 experiment comparable treatments were used but the nutrient under test was Zn and three rates of 0, 2.5
 96 and 5.0 kg Zn ha⁻¹ were applied while N and P were applied at adequate rates of 100 and 20 kg ha⁻¹,
 97 respectively. The five treatments were designated as T1= N₀S₀Zn₀, T2= N₀S₂₀Zn₅, T3= N₁₀₀S₂₀ Zn₀, T4=
 98 N₁₀₀S₂₀ Zn_{2.5} and T5= N₁₀₀S₂₀ Zn₅. The subscript number on each element indicates nutrient rates applied
 99 in kg ha⁻¹. Other necessary nutrients (i.e. P, K, Mg and Ca) were applied to all treatments except the
 100 absolute control, to avoid untargeted nutrients from limiting the response of rice to S and Zn as per soil
 101 test results obtained. The experimental units were arranged in a randomized complete block design
 102 (RCBD) with three replicates. Potassium was applied as KCl, phosphorus as triple super phosphate
 103 (TSP), zinc as ZnSO₄, calcium as CaSO₄ in the Zn experiment or CaCl₂ in the S experiment, and
 104 magnesium as MgSO₄ in the Zn experiment MgCl₂ in the S experiment. All nutrients were applied at
 105 planting except N, for which 60 % was applied at 21 days after transplanting/ or sowing and 40 % was
 106 applied 28 days after the first N application making a total rate of 100 kg N ha⁻¹ applied as urea.
 107 Land ploughing, harrowing and levelling was done using hand hoe twenty days before planting. Bunds
 108 were used to demarcate the blocks and plots and to minimize water movement from one plot to another.
 109 Each specific treatment was allocated within a plot making five plots within a block. The space between
 110 blocks was 1 m while the distance between the plots was 0.5 m and the plot area was 12 m².
 111 Fertilizers to supply nutrients except N were broadcasted and thoroughly mixed using hand hoes before
 112 sowing/ transplanting.
 113 Different sowing systems were used: direct sowing at Mbasia and Kisawasawa while raising seedlings in a
 114 nursery followed by transplanting was done at Mkula. The spacing was maintained as 0.2 m x 0.2 m for
 115 both direct sowing and transplanting. Direct sowing was done by sowing four to five seeds per hill then
 116 thinning was done to leave two plants per hill 14 days after sowing (DAS). The nursery at Mkula was
 117 maintained for 18 days before transplanting the plants to plots. Two water management scenarios were
 118 used namely: sole dependence on rainfall used at Mbasia and Kisawasawa while at Mkula rainfall was
 119 supplemented with irrigation to maintain flooding. Flooding was done at 18 DAS or immediately after
 120 transplanting and was continually maintained up to 10 days before rice harvesting. A pesticide Blast 60
 121 EC (active ingredient Acetamiprid + Lambdacyhalothrin) was used once at 35 days after sowing (DAS) to
 122 control white flies and other pests.

2.4.2 Rice plant sampling, sample preparations and analysis

Rice plant samples were collected at booting stage (75 DAS). Three hills from the mid two rows in each plot were selected randomly and cut at 1 cm above the ground. The shoots were cleaned with distilled water, and then dried at 70°C to attain constant weight. The dried shoots were weighed, ground with a cyclone mill and sieved through a 1-mm sieve for plant analysis. The remaining plants in the field were grown to maturity.

The plant samples were digested in a digestion block at 125 °C using the HNO₃- H₂O₂ wet digestion procedure [23]. In the digest, using BaCl₂ turbidity method, extracted sulphur was determined by using a spectrophotometer [23]. While in the same digest, Zn was determined by atomic absorption spectroscopy [23].

2.4.3 Harvesting of rice and grain yield determination

The grain yield (GY) was obtained at maturity (120 days after sowing) by harvesting panicles. One border row in each side (20 cm) was not harvested and only panicles of inner rows were harvested making a harvest area of 9.36 m². The harvested rice was then threshed, sun dried to achieve moisture content of about 14% and winnowed to remove unfilled grains before weighing. The GY was expressed in t ha⁻¹.

2.5 Statistical Data analysis

All the data collected, including grain yield (GY) and nutrients concentration in rice shoots in response to S and Zn were subjected to analysis of variance using Gen-Stat Discovery Edition 15. Means were compared by Duncan Multiple Range Test (DMRT) at $P = 0.05$. The coefficient of variation (CV) in percent and least significant difference (LSD) were reported.

3.0 RESULTS AND DISCUSSION

3.1. Soil Properties of the Study Sites

Soil characteristics of the three sites used in this study are given in Table 1. The pH ranged between 4.5 and 5.9 for the three sites which was medium at Kisawasawa while low at Mbasaa and Mkula sites. [10]

rated pH < 5.5 as low and 5.5 to 7.0 as medium. Potassium concentration in soil ranged between 0.18 to 0.26 (cmol (+) kg⁻¹) which fall in low to medium ranges [10] rated < 0.2 (cmol (+) kg⁻¹) as low K and from 0.2 to 0.4 (cmol (+) kg⁻¹) as medium. All the three study sites had low total N (i.e. 0.11 – 0.16 %). According to [11] total nitrogen (TN) is rated as ≤ 0.1 % very low, 0.1 to 0.2 % as low and 0.2 to 0.5 % as medium TN. [4] reported that nine out of 20 sites had ≤ 0.2 % total N. Extractable S ranged from 1.3 to 4.5 mg kg⁻¹. [11] reported sulphur critical range to be 6 to 12 mg kg⁻¹ below which response to S fertilizers is expected and vice versa. [9] demonstrated 10 mg kg⁻¹ as a critical concentration for S in soils of Kilombero district. Soil Zn concentration ranged between 0.5 to 2.6 mg kg⁻¹ rated as low to high and a response to Zn was expected at Mbasa site only [9, 10, 24].

Table 1: Selected soil chemical properties of the study sites

Site	Site Location (Coordinates)	pH	TN (%)	P mg kg ⁻¹	K (cmol (+) kg ⁻¹)	Mg (cmol (+) kg ⁻¹)	Ca (cmol (+) kg ⁻¹)	Na (cmol (+) kg ⁻¹)	S mg kg ⁻¹	Zn mg kg ⁻¹
Mkula	036°55'08.1" E 07°47'41.4" S	5.9	0.13	2.2	0.18	6.0	4.5	0.1	4.5	1.6
Mbasa	036°42'42.8" E 08°05'46.0" S	4.5	0.11	1.9	0.14	0.9	0.1	0.4	1.3	0.5
Kisawasawa	036°53'4" E 08°05'46.0" S	5.1	0.16	12.6	0.26	4.7	2.8	0.5	1.9	2.6

3.2 Response of Rice to S and Zn Application under Field Conditions in Kilombero Valley

3.2.1 Response of rice to s application

3.2.1.1 Mkula sites

The grain yield and shoot S concentrations recorded at Mkula A and B sites during 2014 and 2015 seasons are presented in Table 2. Grain yield at Mkula A site ranged between 2.83 and 7.27 t ha⁻¹; the lowest yield from absolute control treatment and the highest from T5. The grain yield at Mkula A site significantly was similarly affected by treatments T2 and T3. An application of N, P, K and Zn while excluding S increased yield by 2.64 t ha⁻¹ over the absolute control. A similar trend was observed at Mkula B site whereby treatment T3 gave significantly higher GY than T1 and the difference was 3.16 t ha⁻¹. Yield at 20 kg S ha⁻¹, (T5) was significantly higher than that at 10 kg S ha⁻¹ in Mkula A site, but at Mkula B site yield at 20 kg S ha⁻¹ was only slightly higher than that at 10 kg S ha⁻¹. Grain yield difference between treatment without S (T3) and the 20 kg S ha⁻¹ treatment (T5), was 1.8 and 1.14 t ha⁻¹ for Mkula A

site and Mkula B site, respectively indicating that application of S was advantageous for rice production. Application of S at 20 kg ha⁻¹ resulted in more than 4 t ha⁻¹ over the absolute control (T1) at both sites indicating that farmers who do not apply all the deficient nutrients in their fields sacrifice a substantial GY. Concentration of S in rice shoots was affected by an application of S at Mkula A and B sites. The treatments which did not receive S (T1 and T3) had low shoot S concentration compared to those that received S. Concentration of S in shoots increased with increasing S application and ranged from 0.22 to 0.29 % for the treatments (T2, T4 and T5) which received S. The treatments without S (i.e. T1 and T3) had low shoot S concentration ranging between 0.14 and 0.15 % indicating an application was important in increasing S concentration in plants.

The response of rice to S (T4 and T5) was expected since the soil at Mkula had lower S concentration than the critical level of 10 mg kg⁻¹ established by [9]. It was also reported that response to S application was expected in soils with S below 5 mg kg⁻¹ using 0.05 M HCl extractant [11]. Similarly, [14] reported the highest grain yield when S was applied at the rate of 30 kg ha⁻¹ in a soil with 7.9 kg S ha⁻¹ (equal to 2.8 mg kg⁻¹) supporting the highest increases in GY in treatments T4 and T5. Comparable results were reported [5, 25] on increased tiller numbers and GY yields. From the above findings, we can generalize that application of S is important in optimizing rice yield and that 20 kg S ha⁻¹ was found to be optimum at Mkula site.

The concentration of S in shoots for the treatments that received S were above the critical range of 0.18 to 0.25 % demonstrated by [9]. At both sites, high values of S in rice shoots occurred in treatments where S (i.e. 10 and 20 kg S ha⁻¹) was applied which also produced high GY compared to other treatments, indicating that application of S had both positive effects on increasing rice GY and S concentration in plants.

However, T1 and T2 treatments recorded concentrations lower than the established range, indicating that low shoot S concentration is associated with low supply of S in soil. [4] found shoot-S concentration below 0.1 % in all the treatments without S in experiments conducted at Mbasia, Kilombero with soil sulphur of 0.22 mg kg⁻¹.

Table 2: Effect of sulphur application on rice grain yield and shoot-S concentration at Mkula A and B sites

Treatment No.	Mkula A site				Mkula B site		
	Nutrient rates (kg ha ⁻¹)	Shoot -S concentration (%)	Grain yield (t ha ⁻¹)	GY change over control (t ha ⁻¹)	Shoot -S concentration (%)	Grain yield (t ha ⁻¹)	GY change over absolute control (t ha ⁻¹)
T1	N ₀ S ₀ Zn ₀	0.15b	2.83e	0	0.15b	2.69c	0
T2	N ₀ S ₂₀ Zn ₅	0.27a	3.77d	2.61	0.24a	2.91c	0.22
T3	N ₁₀₀ S ₀ Zn ₅	0.14b	5.47c	2.64	0.14b	5.85b	3.16
T4	N ₁₀₀ S ₁₀ Zn ₅	0.29a	6.18b	3.35	0.26a	6.59ab	3.9
T5	N ₁₀₀ S ₂₀ Zn ₅	0.27a	7.27a	4.44	0.27a	6.99a	4.3
	LSD	0.04	0.618		0.028	0.776	
	CV. (%)	9.7	6.4		7.1	8.20	

Means in the same column bearing the same letter(s) are not significantly different at $P=0.05$; CV. = Coefficient of variations. LSD = Least significant difference; Treatment rates abbreviations with subscript numbers indicate the nutrient rates applied in kg ha⁻¹. "T" followed by a number indicates the treatment number.

3.2.1.2 Mbasa and Kisawasawa sites

The GY and shoot S concentration data recorded at Mbasa and Kisawasawa sites are presented in Table 3. At Mbasa site, grain yield was increased by S application and ranged between 1.61 t ha⁻¹ and 7.39 t ha⁻¹ in the absolute control and the treatment received 20 kg S ha⁻¹, respectively. The two S levels tested, i.e. 10 and 20 kg S ha⁻¹, respectively produced comparable grain yields. Application of other nutrients without N (T2) produced significantly higher yield than the absolute control (T1) treatment. However, the highest yield was obtained when N and S plus other nutrients were applied together (T5). The statistical significance observed between the S applied (T4 and T5) and S without (T3) treatment indicated that N alone was not beneficial in increasing GY unless S was applied. An application of S either at 10 or at 20 kg ha⁻¹ (T4 and T5) produced 5 t ha⁻¹ more GY than the absolute control (T1) treatment indicating that S application was more beneficial in rice grain production.

Grain yield at Kisawasawa was influenced by S application and of the rates of 10 and 20 kg S ha⁻¹ had comparable grain yields. Exclusion of N while applying S (T2) did not increase yield significantly and the treatments recorded very low GY compared to other treatments. The trend of S application rice yield at Kisawasawa was comparable to the other sites (Mkula and Mbasa). An application of S either at 10 or at 20 kg S ha⁻¹ (T4 and T5) increased rice grain by about 4 t ha⁻¹ demonstrating the importance of S in increasing GY.

Concentration of S in rice shoots at Mbasa site ranged between 0.14 and 0.24 % and was low in treatments that did not receive S (T3) and the absolute control (T1). The S concentration increased with increasing S application i.e. 10 and 20 kg S ha⁻¹ and the highest concentration (0.22%) although not significantly different from that in the control treatment was recorded in treatments T4 and T5. A similar trend was found for grain yield.

The increases in GY and shoot S concentration at Mbasa and Kisawasawa sites due to S application were expected since the soils had 1.3 and 1.9 mg S kg⁻¹, respectively. This concentration falls in the low category compared to the critical range of 6-12 mg kg⁻¹ suggested by several authors including [9,10,11,26].

Table 3: Effect of sulphur application on rice grain yield and shoot S concentration at Mbasa and Kisawasawa sites

Treatment No.	Mbasa				Kisawasawa		
	Nutrient rates (kg ha ⁻¹)	Shoot -S concentration (%)	Grain yield (t ha ⁻¹)	GY change above absolute control	Shoot -S concentration (%)	Grain yield (t ha ⁻¹)	GY change over absolute control (t ha ⁻¹)
T ₁	N ₀ S ₀ Zn ₀	0.14c	1.61d	-	0.16c	2.47c	-
T ₂	N ₀ S ₂₀ Zn ₅	0.19b	2.13c	0.52	0.20b	2.56c	0.09
T ₃	N ₁₀₀ S ₀ Zn ₅	0.13c	4.57b	2.96	0.16c	4.95b	2.48
T ₄	N ₁₀₀ S ₁₀ Zn ₅	0.23a	7.08a	5.47	0.21a	6.45a	4.29
T ₅	N ₁₀₀ S ₂₀ Zn ₅	0.24a	7.39a	5.78	0.22a	6.76a	3.98
	LSD	0.045	0.509		0.039	0.493	
	CV (%)	13.2	5.9		11	5.7	

Means in the same column bearing the same letter(s) are not significantly different at P=0.05; CV. = Coefficient of variations. LSD = Least significant difference; Treatment rates abbreviations with subscript numbers indicate the nutrient rates applied in kg/ ha. "T" followed by a number indicates the treatment number.

The results for the two sites are in conformity with other researchers [6, 14, 27, 28] who reported that S application increased yield components of rice and GY. From the overall results of Mbasa and Kisawasawa sites, it is apparent that sulphur plays an important role in determining the yield and shoot S concentration of rice and that T4 and T5 treatments with 10 and 20 kg S ha⁻¹ performed equally well. Therefore, an application of 10 kg S ha⁻¹ is recommended for optimum yields of rice at the two sites. From the above discussion, it was concluded that the four sites had low levels of S in soils. Application of S increased rice grain yield from 5.47 to 7.27 t ha⁻¹ and S- shoot concentration from 0.14 to 0.29 % at Mkula site. It also increased rice grain yield from 4.57 to 7.39 t ha⁻¹ and shoot –S concentration from 0.13

250 to 0.24% at Mbasa while at Kisawasawa GY increased from 4.95 to 6.76 t ha⁻¹ and shoot -S concentration
251 increased from 0.16 to 0.22 %.

252

253 **3.2.2 Response of rice to Zn application under field conditions at four study sites**

254 **3.2.2.1 Mkula sites**

255 The Zn-shoot concentration and GY for Mkula A and B sites are presented in Table 4. At both sites,
256 application of either Zn at 2.5 or 5 kg/ ha (T4 and T5) did not increase grain yield significantly. Similarly,
257 Zn application did not increase shoot Zn concentration significantly

258 **Table 4. Effect of zinc application on rice grain yield and shoot Zn concentration, at Mkula A and**
259 **B sites**

Treat ment No.	Mkula A site				Mkula B site		
	Nutrient rates (kg ha ⁻¹)	Shoot -Zn concentration (mg kg ⁻¹)	Grain yield (t ha ⁻¹)	GY change absolute over control (t ha ⁻¹)	Shoot -Zn concentratio n (mg kg ⁻¹)	Grain yield (t ha ⁻¹)	GY change over absolute control (t ha ⁻¹)
T ₁	N ₀ S ₀ Zn ₀	25.8a	2.83a	-	24.6b	2.69b	-
T ₂	N ₀ S ₂₀ Zn ₅	27.5a	3.77b	0.94	28.9b	2.91b	0.22
T ₃	N ₁₀₀ S ₂₀ Zn ₀	26.7a	7.19c	4.36	29.6b	6.73a	4.04
T ₄	N ₁₀₀ S ₂₀ Zn _{2.5}	26.3a	7.05c	4.22	29.3b	6.88a	4.19
T ₅	N ₁₀₀ S ₂₀ Zn ₅	26.6a	7.27c	4.44	35.3a	6.99a	4.3
	LSD	4.104	0.555		5.29	0.751	
	CV. (%)	8.1	5.2		9.5	7.6	

260 *Means in the same column bearing the same letter(s) are not significantly different at P=0.05; CV. = Coefficient of variations. LSD =*
261 *Least significant difference; Treatment rates abbreviations with subscript numbers indicate the nutrient rates applied in kg/ ha. "T"*
262 *followed by a number indicates the treatment number.*

263

264 In fact all the shoot Zn concentration values fell in a narrow range of 24.4-35.5 mg kg⁻¹ which falls in the
265 sufficiency range of 25-50 mg kg⁻¹ reported by [11]. It can be generalized that some soils with high levels
266 (above 1.4 mg kg⁻¹) of Zn like Mkula in Kilombero District might not need Zn application.

267 **3.2.2.2 Mbasa site**

268

269 The results of GY and shoot Zn concentration recorded at Mbasa site during 2014 are presented in Table
270 5. Zinc application at either 2.5 or 5 kg Zn ha⁻¹ with all other necessary nutrients (T4 and T5) increased
271 yield significantly above the Zn control but yields of T4 and T5 were comparable. There was a grain yield
272 difference of about 2.8 t ha⁻¹ when 5 kg Zn ha⁻¹ was applied over the treatment which received all other
273 necessary nutrients but without Zn application that indicating the use of Zn was very crucial. The shoot-Zn

274 concentration increased gradually with increased Zn rates. The lowest shoot-Zn concentration was
275 recorded in the treatments without Zn (T1 and T3) which were below the critical concentration.

276 [6] reported an application of Zn on top of N, P, K, and S significantly increased GY of about 5.5 % in
277 comparison to non zinc containing treatment. The results of the present investigation are in agreement
278 with other workers. [29] found significant increase in rice grain yield at three sites in Tabora district,
279 Tanzania with soil- zinc < 0.64 mg kg⁻¹ after applying 20 and 10 kg of ZnSO₄ and ZnO, respectively.

280 **Table 5: Effect of zinc application on rice grain yield and shoot Zn concentration at Mbasa and**
281 **Kisawasawa sites**

Treat ment No.	Mbasa site				Kisawasawa site		
	Nutrient rates (kg ha ⁻¹)	Shoot - Zn concentr ation (mg kg ⁻¹)	Grain yield (t ha ⁻¹)	GY change absolute over control (t ha ⁻¹)	Shoot -Zn concentratio n (mg kg ⁻¹)	Grain yield (t ha ⁻¹)	GY change over absolute control (t ha ⁻¹)
T ₁	N ₀ S ₀ Zn ₀	13.02c	1.62d		23.6a	2.47a	
T ₂	N ₀ S ₂₀ Zn ₅	19.3b	2.13c	0.51	27.4a	2.56a	0.09
T ₃	N ₁₀₀ S ₂₀ Zn ₀	11.51c	4.56b	2.78	26.7a	6.41b	3.94
T ₄	N ₁₀₀ S ₂₀ Zn _{2.5}	19.03b	7.09a	5.59	27.9a	6.33b	3.86
T ₅	N ₁₀₀ S ₂₀ Zn ₅	27.01a	7.39a	5.77	29.6a	6.76b	3.98
	LSD	2.65	0.509		7.270	0.436	
	CV (%)	7.8	8.9		14.3	4.6	

282 *Means in the same column bearing the same letter(s) are not significantly different at P=0.05; CV. = Coefficient of variations. LSD =*
283 *Least significant difference; Treatment rates abbreviations with subscript numbers indicate the nutrient rates applied in kg/ ha. "T"*
284 *followed by a number indicates the treatment number.*

285
286 Likewise, [16] reported 86 % increase in grain yield after application of 5 mg Zn kg⁻¹ soil in a pot
287 experiment using a soil with 0.86 mg kg⁻¹. In the same experiment Zn application increased, shoot Zn
288 concentration from 19.74 mg kg⁻¹ in the control to 43.93 mg kg⁻¹ at 7.5 mg Zn mg kg⁻¹ soil. [12] reported
289 ZnSO₄ application at a rate of 6 mg Zn kg⁻¹ soil applied to a soil with DTPA available Zn of 0.9 mg kg⁻¹
290 increased grain yield by 41 %. From the current study an application of 2.5 kg Zn ha⁻¹ is recommended
291 for optimum yield of rice at Mbasa site.

292 **3.2.2.3 Kisawasawa site**

293
294 The results of GY and Zn concentration in rice shoots recorded at Kisawasawa site are presented in
295 Table 5. Similar to Mkula sites, Zn application did not increase rice grain yield and shoot Zn concentration
296 significantly over the control at Kisawasawa site. However, application of N and S plus other limiting

nutrients other than Zn increased grain yield significantly. These results indicated that the soil at Kisawasawa site had enough Zn for rice growth and yield. The results are in conformity with some researchers who reported that soils with sufficient levels of Zn do not to respond to Zn application [9, 11, 14]. Shoot Zinc concentration were in the range of 23.6 and 29.5 mg kg⁻¹, which falls in the sufficiency range of 18 to 50 mg kg⁻¹ reported by [9, 11, 30]. From this study Kisawasawa soil with Zn concentration above 1.4 mg kg⁻¹ might not need application of Zn.

It was generalized from the above discussion that the three sites (Mkula A and B and Kisawasawa) had sufficient Zn supply at present and only Mbasaa site had deficient Zn in soil. Application of 2.5 kg Zn ha⁻¹ was found to be the optimum rate for Mbasaa.

4. CONCLUSIONS

It was concluded that:

- There was a response of rice plants to S application whereby S application increased rice grain yield by 1.8 t ha⁻¹ and shoot S concentration from 0.13 to 0.29 % at Mkula sites. It also increased rice grain yield by 2.82 t ha⁻¹ and shoot -S concentration from 0.13 to 0.24 % at Mbasaa while at Kisawasawa GY was increased by 1.81 t ha⁻¹ and shoot –S concentration from 0.16 to 0.22 %. Application of 10 kg S ha⁻¹ was recommended as optimum rate for Mbasaa and Kisawasawa while 20 kg S ha⁻¹ was recommended for Mkula site.
- Zinc application increased yield significantly only at Mbasaa site by 2.83 t ha⁻¹. The optimum rate of Zn in Mbasaa is 2.5 kg Zn ha⁻¹, while Mkula and Kisawasawa sites do not need application of Zn at present.

5. REFERENCES

1. Kilima FTM. Scaling up Minjingu phosphate utilization for balanced fertilization of crops in Tanzania. Participatory socio-economic and agronomic baseline survey Report.. Sokoine University of Agriculture, Morogoro. 2011; 51.
2. Mghase JJ. Agronomic and social- economic constraints to high yield of upland rice in Tanzania. Afri. J.Agric. Res. 2010. 5 (2): 150 -158.

- 323 3. Amuri N, Semoka JMR, Ikerra S, Kulaya I, Msuya-Bengesi CP. Enhancing use of phosphorus
324 fertilizers for maize and rice production in small scale farming in Eastern and Northern zones,
325 Tanzania. A Paper presented at the 27th Soil Sc Soc East Afr -6th Afr Soil Sci Soc Conference, 21st
326 to 25th October 2013, Nakuru, Kenya. 2013;121.
- 327 4. Gharibu FN. Effectiveness of Minjingu Mazao as A Source Of Phosphorus, Zinc and Copper in Rice
328 Production In Kilombero District- Morogoro, Tanzania. Dissertation for Award of MSc. Soil Science
329 and Land Management of Sokoine University of Agriculture Morogoro, Tanzania. 2014; 87.
- 330 5. Brady NC, Weil RR. The Nature and Properties of Soils. 14th ed. New Jersey: Pearson Prentice
331 Hall; 2008.
- 332 6. Trivedi, VK., Pandey, MR, Pathak RK. Kala DC. Balanced Use of Nutrients for High Crop Yield
333 and Quality of Rice in Central Uttar Pradesh. Inter. J. Tech. Res. Applic.2015; (3) 4:344-346
- 334 7. Sabugo, RT. Adaptation strategies by smallholder rice farmers under the influence of climate
335 change: a case of Kilombero basin, Tanzania. Dissertation for Award of Degree of Master of Art in
336 Rural MSc Degree at SUA, Morogoro, Tanzania.; 2013; 97.
- 337 8. Kato, F. Development of major rice cultivation area in the KilomberoValley, Tanzania. Afri study
338 Monogr. 2007; 36: 3- 18
- 339 9. Kalala, AM, Amuri, AN Semoka, JMR. Sulphur and Zinc Fertilization Effects on Growth and Yield
340 Response of Rice. Intern J Plant and Soil Sci. 2016; 11(5): 1-12
- 341 10. Landon JR. Booker Tropical Soil Manual: A handbook for soil survey and agricultural land
342 evaluation in the tropics and subtropics. John Wiley and Sons: New York. 1991; pp. 450
- 343 11. Dobermann A, Fairhust T. Rice nutrient disorders and nutrient and nutrient management.
344 International Rice Research Institute. Potash and Phosphate Institute, of Canada, and International
345 Rice Research Institute, Singapore and Los Baños. 2000; 203.
- 346 12. Huda NM, Islam MR, Jahiruddin M. Evaluation of extractants and critical limits of sulphur in rice
347 soils of Bangladesh. Asian J Plant Sci. 2004; 3: 480-483.
- 348 13. Brosnan JT, Brosnan ME. the sulfur-containing amino acids: An Overview. J. Nutrit. 2006; 136 (6):
349 1636-1640

- 350 14. Singh AK, Manibhushan, Meena MK, Upadhyaya MA. Effect of sulphur and zinc on rice
351 performance and nutrient dynamics in plants and soil of Indo Gangetic Plains. J Agr Sci. 2012; 4:
352 (10): 162 -170.
- 353 15. Ahmad, HR., Aziz T, Hussain S, Akraam M, Sabir M, Khashif SUR, Hanafi MM. Zinc-enriched farm
354 yard manure improves grain yield and grain zinc concentration in rice grown on a saline-sodic soil.
355 Intern. J Agricul Biol. 2012; 14: 787-792.
- 356 16. Muthukumararaja TM, Sriramachandrasekharan MV. Effect of zinc on yield, zinc nutrition and zinc
357 use efficiency of lowland rice. J Agr Techn. 2012; 8: 551-561
- 358 17. McLean, EO Soil pH and Lime requirement: In: Methods of soil analysis part2 (edited by AI Page;
359 RH Miller and DR Keeney) Amer Soc Agron Soil Sci Amer Inc., Madison, Wisconsin. 1982. pp 191-
360 224.
- 361 18. Bray, R. H. and Kurtz, L. T. Determination of total, organic and available forms of phosphorus in
362 soil. Soil Sci. 1945; 59: 39–45.
- 363 19. Murphy J, Riley JP. A modified single solution method for the determination of phosphates in
364 natural waters. Anal Chem Acta. 1962; 27:31-36.
- 365 20. Thomas GW. Exchangeable cations. In: Methods of Soil Analysis. Amer Soc Agron Monogr. 1996;
366 9:149-157.
- 367 21. Lindsay WL , Norvel WA. Development of a DTPA test for zinc, iron, manganese and copper. Soil
368 Sci Soc Amer J. 1978; 42:421-428
- 369 22. Moberg JR. Soil and plant analysis manual. The Royal Veterinary and Agriculture University,
370 Chemistry Department, Copenhagen, Denmark. 2000; 133.
- 371 23. Okalebo JR, Gathua KW, Woomer, PL. Laboratory methods of soil analysis. A working manual
372 KARI, Nairobi, Kenya. 1993.
- 373 24. Msolla, MM. Response of rice to Zinc in Igunga and Nzega Districts. A Dissertation for Award of
374 MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 1991; 152.
- 375 25. Blair GJ, Lefroy RDB. Sulphur cycling in tropical soils and the agronomic impact of increasing use
376 of S free fertilizers, increased crop production and burning of crop residue. In: Proceedings of the

- 377 Symposium on Fertilizer Sulphur Requirements and Sources in Developing Countries of Asia and
378 the Pacific. 1987; pp. 12-17.
- 379 26. Thiagalingam K. Soil and plant sample collection, preparation and interpretation of chemical
380 analysis. A training manual and guide. Australian Contribution to a National Agricultural Research
381 System in PNG (ACNARS), Adelaide: Australia. 2000; p. 49.
- 382 27. Ali MM, Mian MS, Islam A, Begum AJ, Ferdous AKM. Interaction effects of sulphur and
383 phosphorus on wetland rice. Asian J. Plant Sci. 2004; 3: 597-601.
- 384 28. Habtegebrial K, Mersha S, Habtu S. Nitrogen and Sulphur fertilizers effects on yield, Nitrogen
385 uptake and nitrogen use efficiency of upland rice variety on irrigated Fulvisols of the Afar Region,
386 Ethiopia. J Soil Sci Environ Managt. 2013; 4(3): 62 -70
- 387 29. Msolla MM, Semoka JMR, Singh BR. Assessment of available zinc for rice in soils of the Tabora
388 region, Tanzania. Norweg J Agricul Sci 1994; 8: 1-12.
- 389 30. Tandon HLS. Methods of Analysis of soils, plants, waters and fertiliers. Fertilizer Development and
390 Consultation Organization. New Delhi, India. 1995. pp 144-146.