



Optimum Levels of Phosphorus and Potassium for Rice in Lowland Areas of Kilombero District, Tanzania

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Abstract: The optimal recommended rates of phosphorus (P) and potassium (K) in the Kilombero valley, Tanzania are outdated. The Objective of the study was to establish optimum rates of P and K for improved rice cultivation in rice fields of Kilombero valley. Two on-farm experiments were carried out in two seasons of January to May 2014 and 2015 at Mkula, Mbasa and Kisawasawa sites in Kilombero district, Tanzania. In the first experiment the treatments were a control for P; adequate levels of N and K plus two rates of phosphorus 10 and 20 kg P /ha. In the second experiment the treatments were a control for K; and two rates of K of either 50 or 100 kg/ha. These three treatments each received adequate levels of N, P and Zn. An absolute control and a control for N treatments were included in both of the experiments. The test crop was rice variety SARO-5. Phosphorus application significantly increased grain yield (GY) by 3.26 and 2.01 t/ha at Mbasa and Mkula, respectively. Also P application increased shoot P concentration from a low level (0.12%) to the adequate range (0.19 - 0.24%) at the two sites. Potassium application increased significantly GY by 2.76 and 1.93 t/ha at Mbasa and Mkula, respectively. Also K application increased shoot K concentration from a low range (1.14 - 1.34%) to the adequate range (2.63 - 2.99%) at the two sites. An application of P and K affected neither shoot K nor P concentrations nor GY at Kisawasawa site. It is recommended that 10 kg P/ha and 50 kg K/ha be used as optimum rate for rice production in P and K deficient soils of Kilombero valley.

Keywords: Optimum P Rate, Optimum K Rate, Lowland- Rainfed, Macronutrients

1. Introduction

Rice (*Oryza sativa* L.) is the second most important staple and cash crop after maize in Tanzania. Kilombero district is one of the potential areas in rice production but has a record of low rice productivity. Recent studies by [1, 2, 3] reported rice yield to range between 0.5 and 2.0 t/ha under rainfed lowlands of Kilombero district. The reported yield is much lower than the potential of the widely grown rice variety TXD 306 commonly known as SARO-5, of 4.3 to 6.5 t /ha [2, 4]. Recently, [5] reported that 43.3% of farmers in Kilombero district have adopted the variety SARO-5 which is high yielding and demands good agronomic practices including nutrients management.

Low soil fertility and imbalanced plant nutrition are important constraints and their improvements may boost rice production in Tanzania rice systems particularly those of Kilombero district. Research shows that only 4 to 6.7% rice producers use inorganic fertilizers, and mostly only nitrogen (N) and phosphorus (P) containing fertilizers [1, 5]. Several research works show that P levels in Kilombero soils is low and limit rice production. For instance, studies by [6, 7] found 60% and 67% respectively, of studied soils under paddy production areas in Kilombero district, have insufficient P for high rice yields. Data reported by [8] indicate that 11 out of 20 studied soils from Kilombero district had P below the critical level of 8 mg/kg established by [9]. Similarly, [9] recently reported that out of 19 sites surveyed in Kilombero district, 42% of soils were deficient in

P. This indicates that P deficiency is becoming an extensive problem in soils used for rice production in Kilombero district, and that P application is needed in order to optimize yield.

Potassium is one of the three essential macronutrients required in large quantities for plant growth and yield [10]. In most cases, K is lost from soils through leaching and burning or removal of plant residues. It is estimated that high amount of K at 14.5 kg is needed for producing one tone of rice [11]. Rice straw removal and burning to clear the land for the succeeding rice crop are common practices in most rice fields of Kilombero. A study [7] showed three out of six paddy soils of Kilombero district had low levels of K. Other researchers [6, 12, 13] also reported low K status in some villages of Kilombero valley. Further, [9] reported 47.3% out of 19 studied soils to contain $K \leq 0.2$ cmol (+)/kg similarly to [8] who reported 15 soils out of 20 to be K deficient. The trend of low K in several soils in Kilombero may necessitate the application of K containing fertilizers.

Optimal rates of P and K application is crucial in achieving good production of rice and has been reported by several researchers. [14] Reported low yields of 1.2, 2.03 and 3.09 t/ha when nutrients were applied by excluding N, P and K in plots, respectively, while a balanced application of 90-26-50 N-P-K gave the yield of 6.84 t/ha. The increased yield due to N, P, and K fertilization demonstrates the importance of optimum rates and balanced nutrition in rice production. [9] Reported an application of 40 and 400 mg/kg as optimum rate for P and K, respectively, in a screen house experiment, which needs to be confirmed under field conditions. [7] Reported a combination of applied 60 and 20 kg/ha as N and P, respectively, resulted in higher rice yield of 5.7 t/ha than 4.7 t/ha of N alone although the difference was not statistically different in Eastern and Northern Zones, of Tanzania.

Generally, despite the importance of P and K and the trend of their low status in soils for rice production, P recommendation by [15] has not been reviewed and updated and there are no established K recommendations for rice production in Kilombero district in Tanzania. Updating fertilizer recommendations requires information on the rice responses to different nutrient rates under current soil and climate conditions. Therefore, the objectives of this study were (i) To determine the response of rice to P and K in the cultivated rice fields in Kilombero valley (ii) To establish optimum rates of P and K for rice in the cultivated rice fields in Kilombero valley.

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out at three villages namely: Mkula, Kisawasawa and Mbasa located in Kilombero district. Kilombero district is located in a range of longitudes 036°00'0" E to 037°00'0" E and latitudes 07°00'0.0" S to

09°00'0.0" S in Morogoro region, Eastern zone of Tanzania, and the main part of the district is comprised of Kilombero Valley which is famous in rice production. The sites elevation ranged between 266 and 318 meters above sea level. During the growing seasons, the temperature ranged between 29.0 and 33.8°C. Total annual rainfall recorded was 1138 mm in season one, and 995 mm in season two, with monthly rains peaks at March and April. The observed total rainfall in two seasons slightly resembles the mean annual rainfall reported by [16], which ranges from 1200 to 1400 mm falling between December to June and annual temperature ranges between 26 and 32°C in Kilombero valley.

2.2. Soil Sampling and Sample Preparation for General Fertility Status

A soil fertility survey was conducted during which, soil samples were collected at a depth of 0 – 20 cm from the representative rice growing areas in the three villages in Kilombero district. In each site a minimum of 10 sub-samples were collected randomly in a relatively uniform area of about 0.5 ha using an auger and mixed thoroughly to constitute a representative composite sample. The soil samples were sent to SUA laboratory, air-dried and ground to pass through a 2-mm sieve ready for analysis

2.3. Soil Analysis

Soil pH was analyzed in a 1: 2.5 soil: water suspension ratio by using a pH meter [17]. Extractable P was determined according to the Bray I method [18] following colour development by phospho-molybdate blue method [19]. Exchangeable cations (Ca, Mg, K and Na) were determined from ammonium acetate (NH₄OAc) leachate [20]. Zinc was determined by Diethylene triamine pentaacetic acid- (DTPA) (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 BaCl₂ turbidity method was used for determination of S concentration [22].

2.4. Field Experiment, Management and Data Collection

2.4.1. Experimental Design

Two field experiments were carried out in three villages namely, Mkula, Mbasa and Kisawasawa for 120 days. The geographic coordinates of the sites are provided in Table 1. The study was carried out in all sites in two different seasons during January to May of 2014 and 2015. At Mkula site, one acre was demarcated in two parts after soil analysis. The first half of the plot was used in the first season (January to May 2014) and the remaining (adjacent) part was used in the second season (January to May 2015), hereafter referred to as Mkula A and B, respectively. Mbasa site was used only during season one (January to May 2014) while Kisawasawa was used during the second season (January to May 2015). The first field experiment was carried out to assess rice response to phosphorus and the second was to assess rice response to potassium.

The treatments tested in the first experiment were i) an absolute control, no fertilizer was applied (T1), ii) a control for N but containing P and K at the rate of 20 kg P/ha and 100 kg K/ha (T2), iii) a control for P but containing N and K at 100 kg N/ha and 100 kg K/ha (T3), iv) N at 100 kg N/ha, K at 100 kg K/ha and P at 10 kg P/ha (T4), and v) N at 100 kg N/ha, K at 100 kg K/ha and P at 20 kg P/ha (T5). These treatments were designated as: T1= N₀P₀K₀, T2= N₀P₂₀K₁₀₀, T3= N₁₀₀P₀K₁₀₀, T4= N₁₀₀P₁₀K₁₀₀, and T5= N₁₀₀P₂₀K₁₀₀. In the second experiment, comparable treatments were used but the nutrient under the test was K at three rates of 0, 50 and 100 kg K per hectare. In this second experiment N and P were applied at the rates of 100 and 20 kg/ha, respectively. The five treatments were also designated as T1= N₀P₀K₀, T2= N₀P₂₀K₁₀₀, T3= N₁₀₀P₂₀K₀, T4= N₁₀₀P₂₀K₅₀ and T5= N₁₀₀P₂₀ K₁₀₀. Letter "T" followed by a number indicate a treatment number while the subscript number on each element indicate nutrient rates applied in kg/ha. Other nutrients (i.e. S, Zn, Mg and Ca) were applied to all treatments to avoid untargeted nutrients from limiting the response of rice to P and K as per soil test results obtained except in the absolute control.

Land ploughing, harrowing and leveling was done using hand hoes 20 days before planting. Soil bunds were used to demarcate the blocks and plots and to minimize water movement from one plot to another. Plots had 4 m length and 3 m width making an area of 12 m², the space between blocks was 1 m while the distance between the plots was 0.5 m. The treatments were randomly allocated to plots within a block. Thus, the experimental units were arranged in a randomized complete block design (RCBD) with three replications (blocks). Different sowing systems were used; direct sowing was used at Mbasa and Kisawasawa while nursery and transplanting was done at Mkula. The plant spacing was 0.2 m x 0.2 m for both direct sowing and transplanting. Direct sowing was done by sowing four to five seeds per hill then thinning was done 14 days after sowing (DAS) to leave two plants per hill. The nursery at Mkula was maintained for 18 days before transplanting the seedlings to plots at a spacing of 0.2 m x 0.2 m.

Potassium was applied as KCl (0-0-50), phosphorus as triple super phosphate (TSP) (0-20-0), zinc applied as ZnSO₄ containing (35.5% Zn) calcium as CaSO₄, and sulphur was applied as MgSO₄ containing 13.0% S. All nutrients were applied at planting except N, for which 60% was applied at 21 days after sowing and 40% was applied 28 days later after first N application, making a total rate of 100 kg N/ha applied as urea (46-0-0). Fertilizers to supply P, K, Ca, Mg and Zn were broadcasted and thoroughly mixed in the soil using hand hoes before sowing/transplanting. Nitrogen fertilizer was also broadcasted at the time described above. Water management had two scenarios whole rainfed dependent at Mbasa and Kisawasawa while at Mkula irrigation was supplemented to maintain flooding. Flooding was done 21 DAS just immediately after transplanting and was continually maintained up to 10 days before rice harvesting.

2.4.2. Fertilizers, Seeds and Inputs Used in the Experiments

Seeds of rice variety TXD 306 commonly known SARO-5 used in the study were obtained from Agricultural Seed Agency (ASA), Tanzania. All fertilizers were obtained from Yara Tanzania. A pesticide Blast 60 EC (active ingredient Acetamiprid + Lambda-cyhalothrin) was used once at 35 days after sowing (DAS) to control white flies and other insects.

2.4.3. Rice Plant Sampling, Sample Preparations and Analysis

Rice plant samples were collected at booting stage (75 DAS). Three hills from the middle 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 for grain yield (GY) determination. The plant samples were digested in a digestion block at 125°C using the HNO₃- H₂O₂ wet digestion procedure [23]. The extracted P in the digest was analyzed following colour development using molybdenum blue method [19]. While in the same digest, K was determined by atomic absorption spectroscopy [23].

2.4.4. Harvesting of Rice and Grain Yield Determination

The grain yield (GY) was obtained at maturity at 120 days by harvesting panicles. One border row in each side (20 cm) was not harvested for the study and only panicles of inner rows were harvested making a harvesting area of 9.36 m². The harvested rice was then threshed, sun dried to maintain constant weight (14% moisture) and winnowed to remove unfilled grains before weighing. The GY weight obtained was expressed in t/ha.

2.5. Statistical Data Analysis

All the data collected consisting of grain yield (GY) and nutrients concentration in rice shoots responses to P and K were subjected to analysis of variance using Gen-Stat Discovery Edition 15. Means were compared by Duncan's Multiple Range Test (DMRT) at *P* = 0.05. The coefficient of variation (CV) in percentage and the least significant difference (LSD) were recorded.

3. Results and Discussion

3.1. Soil Properties of the Study Sites

The soil characteristics of the three sites used in this study are given in Table 1. Soil pH was 4.5 in Mbasa, 5.1 in Kisawasawa and 5.9 in Mkula, which was low to medium referring to [24] who rated pH < 5.5 as low and 5.5 to 7.0 as medium. Kisawasawa and Mbasa soil pH was low while Mkula was medium. Potassium concentration in soil ranged from 0.18 to 0.26 cmol (+)/kg (Table 1), which is low to medium, respectively. [24] Rated < 0.2 cmol (+)/kg as low K and from 0.2 to 0.4 cmol (+)/kg as medium. Calcium

concentration ranged from 0.9 to 6.0 cmol (+)/kg, indicating that the nutrient was very low at Mbasas, low at Kisawasawa and medium at Mkula site. Exchangeable magnesium concentration ranged between 0.1 and 4.5 cmol (+)/kg, indicating that the nutrient was low in Mbasas and high at Mkula and Kisawasawa. [24] Rated Ca (in cmol (+)/kg) as follows: < 2.0 as very low, 2.0 to 5.0 as low, 5.1 to 10.0 as medium, and 10.1 to 20.0 as high while > 20.0 as very high. Magnesium was rated < 0.2 cmol (+)/kg as low, 0.2 to 0.5 as medium and > 0.5 cmol (+)/kg as high. All the three study sites had low total N (TN) (i.e. 0.11 – 0.16%). The TN ratings are according to [24] who rated TN as ≤ 0.1% very low, 0.1 to 0.2% as low and 0.2 to 0.5% as medium TN. Extractable S of the three sites ranged from 1.3 to 4.5 mg/kg.

[24] Rated sulphur from 6 to 12 mg/kg as a critical range whereby below to it response to S fertilizers is expected and *vice versa*. Zinc content at Mbasas was low while the concentration was sufficient at Mkula and Kisawasawa according to [24] gave a range of 1.0 to 1.4 mg/kg as critical range where below this, a response to Zn fertilizer was expected. Phosphorus was low in Mbasas and Mkula (< 8.0 mg/kg) sites but was high in Kisawasawa [9, 24]. The soil pH of all sites was favorable for rice production. [25] Reported a pH range of 4.5 to 6.5 satisfactory for rice production under flooded conditions. The nutrients discussed above which were below the recommended critical concentration were applied in order to avoid nutrient imbalance that could limit P and K responses.

Table 1. Selected chemical properties of the study sites in Kilombero district, Tanzania.

Site	Site Location (Coordinates)	pH	TN (%)	P (mg/kg)	K (cmol (+)/kg)	Mg (cmol (+)/kg)	Ca (cmol (+)/kg)	Na (cmol (+)/kg)	S (mg/kg)	Zn (mg/kg)
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
Mbasas	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 P Application under Field Conditions in Kilombero Valley

Grain yield and P-shoot concentration of rice from Mkula sites A and B during 2014 and 2015, respectively are presented in Table 2. At Mkula A and B sites the concentration of P in rice shoots was affected by P application. The lowest P- shoots concentration (i.e. ≤ 0.13%) was recorded in the treatments T1 and T3 which did not receive P in both sites. The treatments that received P either at 10 or 20 kg /ha (T2, T4 and T5) had statistically similar P concentration ranging from 0.22 to 0.24% in their rice shoots in Mkula A (Table 2). At Mkula B treatment T5 that received 20 kg P/ha had significantly greater shoot P concentration of 0.23% than T4 that with 10 kg P/ha which had 0.21% P concentration in rice shoot indicating P application increased shoot P concentration (Table 2).

Application of P at Mkula site A and B had a significant effect on grain yield in all the treatments that received P fertilizer. An absolute control (T1) produced lowest grain yield of all the treatments. Application of other nutrients excluding N (T2 treatment) had significantly lower grain yields of 3.77 and 2.91 t/ha, in site A and B, respectively, than those with N (> 5 t/ha) regardless of P application (T3, T4 and T5). A treatment that received other nutrients except P (T3) gave lower GY (< 6 t/ha) than the treatments T4 and T5 that received all nutrients which had GY > 6.8 t/ha in both Mkula site A and B. An application of other nutrients except P (T3) gave a GY difference of 2.43 to 3.09 t/ha to treatment T1 at Mkula sites. Application of all nutrients including P (T4 and T5) significantly gave GY change ranging between 0.78 to 2.01 t/ha relative to T3, indicating that P was important in increasing GY in both sites of Mkula.

Table 2. Effect of phosphorus application on grain yield (GY) and shoot P-concentration at Mkula site during 2014 growing season (Mkula A) and during 2015 growing season (Mkula B), Kilombero district.

Treat. No.	Mkula site A				Mkula site B			
	Nutrient rates (kg/ha)	Shoot -P concentration (%)	Grain yield (t/ha)	GY change due to P application (t/ha)	Shoot-P concentration (%)	Grain yield (t/ha)	GY change due to P application (t/ha)	
T1	N ₀ P ₀ K ₀	0.13b	2.83d		0.12c	2.69c		
T2	N ₀ P ₂₀ K ₁₀₀	0.22a	3.77c		0.21b	2.91c		
T3	N ₁₀₀ P ₀ K ₁₀₀	0.13b	5.26b		0.12c	5.78b		
T4	N ₁₀₀ P ₁₀ K ₁₀₀	0.22a	6.89a	1.63	0.21b	6.56a	0.78	
T5	N ₁₀₀ P ₂₀ K ₁₀₀	0.24a	7.27a	2.01	0.23a	6.99a	1.21	
LSD		0.029	0.769		0.014	0.748		
CV %		8.1	7.9		4.3	8.0		

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; "T" followed by a number indicates the treatment number; Nutrient rates abbreviations with subscript numbers indicate the nutrient rates applied in kg/ha.

Effects of phosphorus on grain yield and shoot P concentration in rice at Mbasa are given in Table 3. The lowest shoot P concentration (0.12%) was obtained in the without P treatment (T3). The treatments with P application i.e. T2, T4 and T5 had significantly higher P concentration than the no P treatment (T3), but did not differ significantly from the control in Mbasa site. The P concentration in treatments with P ranged from 0.17 to 0.19%. Application of P had a significant increased grain yield in Mbasa site (Table 3). An application of other nutrients except P (T3) treatment had significantly lower grain yield than those applied with P (T4 and T5) but higher GY than the T1 and T2 treatments in Mbasa site. An absolute control (T1) and without N (T2) treatments produced significantly lowest grain yield of all the treatments indicating N was important. Similar to Mkula sites, an application of P at 10 and 20 kg/ha (T4 and T5) treatments had statistically equal grain yields in Mbasa site (Table 3). The high difference of GY over absolute control at Mbasa site was 5.77 t/ha obtained by applying P at 20 kg

P/ha compared to 2.51 t/ha obtained when all nutrients were applied excluding P (T3). Compared to treatment without P but with other necessary nutrients (T3), application of 20 kg P /ha brought a significant increase of 3.26 t/ha indicating P was very beneficial to raise GY.

Phosphorus application at 10 and 20 kg P/ha with other nutrients (T4) and (T5), respectively, did not differ significantly in grain yield and shoot P concentration at Kisawasawa site (Table 3). An absolute control and without N treatments (T1 and T2) produced significantly lower grain yield than other treatments. All the treatments that received P (T4 and T5) with other necessary nutrients had statistically similar to GY compared to the T3 treatment although there was numerical increase in GY. A small insignificant positive change in GY due to P application ≤ 0.44 t/ha was observed between treatments received P (T4, T5) and without P treatment (T3). This scenario differs to other sites of Mkula and Mbasa where P application increased GY significantly compared to the treatments without P application.

Table 3. Effect of phosphorus application on P-concentration and grain yield (GY) at Mbasa and Kisawasawa sites in Kilombero district, Tanzania.

Treat. No.	Mbasa site			GY change due to P application (t/ha)	Kisawasawa site		
	Nutrient rates (kg/ha)	Shoot-P concentration (%)	Grain yield (t/ha)		Shoot-P concentration (%)	Grain yield (t/ha)	GY change due to P application (t/ha)
T1	N ₀ P ₀ K ₀	0.18a	1.62c		0.19a	2.47b	
T2	N ₀ P ₂₀ K ₁₀₀	0.19a	2.13c		0.21a	2.56b	
T3	N ₁₀₀ P ₀ K ₁₀₀	0.12b	4.13b		0.19a	6.33a	
T4	N ₁₀₀ P ₁₀ K ₁₀₀	0.17a	6.54a	2.41	0.21a	6.66a	0.33
T5	N ₁₀₀ P ₂₀ K ₁₀₀	0.18a	7.39a	3.26	0.22a	6.77a	0.44
	LSD	0.017	0.859		0.0298	0.595	
	CV %	5.4	10.3		7.7	6.4	

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; "T" followed by a number indicates the treatment number; Treatment rates abbreviations with subscript numbers indicate the nutrient rates applied in kg/ha.

The significant effects of P application on grain yield at Mbasa, Mkula site A and B was expected because the concentration of P in soil was low (Table 1). These results are consistent with the results from the earlier screen house study by [9] indicating soil with low P need an application of P to attain higher grain yields. Lowest yield in the absolute control indicates that farmers who do not apply P containing fertilizers are at risk of obtaining low yields even if they use other best crop husbandry. A low grain yield when N fertilizer was excluded is due to low levels of N in soils (Table 1). [14] Reported an increase in GY when 90 kg N/ha was applied in rice production lowlands of Ghana. [14] Support these results by reporting that exclusion of N resulted on 1.29 t/ha compared to 6.84 t/ha of rice due to application of combined NPK. [14] Also reported 26 kg P/ha as optimum rate for the soil with P less than 2 mg/kg. A review by [15] gave a blanket recommendation of 10 kg P/ha as optimum rate for paddy soils of Kilombero valley.

The shoot P concentration of all the treatments at Kisawasawa ranged between (0.19 and 0.22%) which is higher to the critical concentration of P in shoots of 0.16 demonstrated by [9]. The study indicates there is no need of

applying P in the soils with high levels of P. The soil at Kisawasawa had higher amount of P of 12.6 mg/kg (Table 1). Therefore the observed trend of no response to fertilizer application was expected in Kisawasawa. From the above discussion, it can be generalized that the sites of Mkula and Mbasa had deficient P concentration in soil and only Kisawasawa had sufficient P in soil. An application of P at Mbasa increased rice grain yield from 4.13 to 7.39 t/ha (3.26 t/ha difference) and P- shoot concentration from 0.12 to 0.19 mg /kg. A similar trend observed at Mkula sites where P application increased GY from 5.26 to 7.27 t/ha (2.01 t /ha) and P-shoot concentration from 0.12 to 0.24%. An application of 10 kg P /ha was recommended as optimum rate for Mbasa and Mkula sites. Kisawasawa had no need of P concentration.

3.3. Response of Rice to Potassium Application Under Field Conditions in the Four Study Sites

Effects of K concentration in shoots and grain yield in rice at Mkula A and B sites are given in Table 4. Concentration of K in rice shoots was affected by K application at both sites and seasons in Mkula. At Mkula A site, low K concentration

(ranging from 1.14 to 1.31%) was recorded in the control (T1) and in the no K (T3) treatments. The treatments that received K (T2, T4 and T5) performed equal on the amount of K concentration ranging between 2.43 and 2.63% in the rice shoots. Concentration of K in plant shoots from Mkula site B ranged from 1.19 to 2.99%. The lowest concentration (ranging from 1.19 to 1.29%) was recorded in the treatments which did not receive K (T1 and T3). The treatments that received K (T2, T4 and T5) had higher K concentration in shoots (ranging from 2.69 to 2.99%) and did not differ significantly from each other. Application of K affected rice grain yield significantly at Mkula A and B sites. An application of other nutrients excluding K (T3 treatment)

produced lower grain yield than the treatments that received K together with other nutrients (T4 and T5) but was above the absolute control and without N (T1 and T2) treatments. An absolute control (T1) produced lowest grain yield of all the treatments. An application of other nutrients excluding N (T₂) treatment had significantly lower GY than those applied with N and K (T1 and T2). An application of other nutrients excluding K (T3) had significantly lower GY than the treatments (T4 and T5) that received K but was higher to the absolute control and without N treatments. An application of K at 50 and 100 kg/ha (T4 and T5) treatments had statistically equal grain yields.

Table 4. Effect of potassium application on shoot-K concentration and grain yield at Mkula site during the 2014 (Mkula A) and during the 2015 (Mkula B) growing season in Kilombero district, Tanzania.

Mkula site A				Mkula site B			
Treat. No.	Nutrient rates (kg/ha)	Shoot-K concentration (%)	Grain yield (t/ha)	GY change due to K application (t/ha)	Shoot-K concentration	Grain yield (t/ha)	GY change due to K application (t/ha)
T1	N ₀ P ₀ K ₀	1.14b	2.83c		1.29b	2.69c	
T2	N ₀ P ₂₀ K ₁₀₀	2.43a	3.77c		2.69a	2.91c	
T3	N ₁₀₀ P ₂₀ K ₀	1.31b	5.34b		1.19b	6.02b	
T4	N ₁₀₀ P ₂₀ K ₅₀	2.58a	7.05a	1.71	2.74a	6.50ba	0.48
T5	N ₁₀₀ P ₂₀ K ₁₀₀	2.63a	7.27a	1.93	2.99a	6.99a	0.97
	LSD	0.288	0.755		0.315	0.718	
	CV %	7.6	7.6		7.8	7.1	

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; "T" followed by a number indicates the treatment number; Treatment rates abbreviations with subscript numbers indicate the nutrient rates applied in kg/ha.

Effects of K on grain yield and K-shoots concentration in rice at Mbasa site are given in Table 5. Like in Mkula sites, concentration of K in rice shoots was affected by K application. The lowest concentration ranged between 1.34 and 1.46% and was recorded in the treatments which did not receive K (T1 and T3 treatments). The treatments T4 and T5 that received 50 and 100 kg K /ha, respectively, performed equally in terms of K concentration (ranging from 1.81 to 2.64%) and was higher than other treatments. Application of K at Mbasa had significant effects on grain yield in all the treatments. An absolute control (T1) did not differ significantly with without N treatment (T2) and they produced lowest grain yield of all the treatments. An application of other nutrients excluding K, the (T3) treatment had significantly lower GY than those applied with K (T4 and T5) although was higher to the (T1 and T2) treatments.

An application of K at 50 and 100 kg/ha (T4 and T5) had relatively similar increase in grain yields at Mbasa site. Considering grain yield from T1, the treatments (T4 and T5) gave a difference of more than 5 t/ha compared to about 3 t/ha of GY produced by exclusion of K in T3 indicating K is very important. Effects of K on grain yield and shoot K concentration in rice at Kisawasawa site are given in Table 5. The lowest concentration was obtained in the treatments which did not receive K including an absolute control but difference was not significant to other treatments. Application of K had no significant effects on grain yield in all the treatments (T3, T4 and T5) with and without K. An absolute control was significantly comparable with N without treatments (T1 and T2) and produced lower grain yield to other treatments. An application of other nutrients excluding K (T2) treatment had lower GY to those received.

Table 5. Effect of potassium application on K-concentration and grain yield at Mbasa and Kisawasawa sites in Kilombero district, Tanzania.

Mbasa site A				Kisawasawa site			
Treat. No.	Nutrient rates (kg/ha)	Shoot-K concentration	Grain yield (t/ha)	GY change due to K application (t/ha)	Shoot-K concentration (%)	Grain yield (t/ha)	GY change due to K application (t/ha)
T1	N ₀ P ₀ K ₀	1.46c	1.62c		2.07a	2.46b	
T2	N ₀ P ₂₀ K ₁₀₀	1.81b	2.13c		2.34a	2.56b	
T3	N ₁₀₀ P ₂₀ K ₀	1.34c	4.63b		2.15a	6.73a	
T4	N ₁₀₀ P ₂₀ K ₅₀	2.64a	7.19a	2.56	2.33a	7.08a	0.35
T5	N ₁₀₀ P ₂₀ K ₁₀₀	2.63a	7.39a	2.76	2.15a	6.76a	0.03
	LSD	0.31	0.515		0.284	0.463	
	CV %	8.3	6.0		6.8	4.8	

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 indicate the nutrient rates applied in kg/ha.

The rice GY and shoot K concentration responded to K at Mbasa, Mkula A and B sites were expected because the soil K concentration at these sites was low (Table 1). Potassium application increased GY and shoot K concentration and other grain yield attributes in the treatments received K which is similarly reported by other several researchers. [9] Reported an increase of K in yield attributes and GY when K was applied in six K deficient soils from Kilombero. Nitrogen was the first limiting nutrient and response to K obtained by including N as observed K application increased GY to about 4 t/ha compared to 0.94 t/ha obtained when N was excluded. The researcher [26] reported tiller numbers and GY increase due to application of 80 kg N/ha in a soil containing 0.08% total nitrogen justifying the significant difference of GY in treatments with and N without. For K response, [27] reported an application of 66 kg K/ha, to increase rice GY which supports the observed increase of GY. Similarly, an increase of grain yield associated with K application at Mkula and Mbasa is justified by [28] who reported a significant increase of rice grain yield after application of 75 kg K/ha in a soil containing 0.08 cmol (+) /kg. The current study observation, an application of 50 and 100 kg/ha performed significantly equal in GY and therefore 50 kg K/ha is recommended as optimum rate for Mkula and Mbasa sites. The rate is within the suggested range of 20 to 100 kg K/ha [29] but also slightly close to the rate 75 kg K/ha [28].

The no response of K applied to soils of Kisawasawa was expected because the soil had high concentration of K (i.e. 2.7 cmol (+)/kg). The established critical level for no response in K fertilizer by several researchers including [9] reported K to be above 0.2 cmol (+)/kg. The similar results of Kisawasawa were reported by [30] that no significant increase in grain yield for the 50 mg K/kg soil treatment applied in 0.4 cmol (+)/kg soil. Therefore, from this study, it can be concluded that the sites of Kisawasawa did not need K application. An application of K at 50 and 100 kg/ha (T4 and T5 treatments) had relatively equal performance in increasing grain yields at this site. The sites of Mkula and Mbasa had deficient K concentration in soil and only Kisawasawa had sufficient K in soil. An application of K at Mbasa increased rice grain yield from 4.63 to 7.39 t/ha (a difference of 2.76 t/ha) and K- shoot concentration from 1.34 to 2.63%. At Mkula sites K application increased GY from 5.34 to 7.27 t/ha (a difference of 1.93 t/ha) and K-shoot concentration from 1.14 to 2.99%. An application of 50 kg K/ha was recommended as optimum rate for Mbasa and Mkula sites. Kisawasawa had no need of K concentration.

4. Conclusions and Recommendations

The results indicates that there is a response of cultivated rice to the application of P and K fertilizer in fields of Kilombero. To obtain a good response of P and K there is a need of addressing all deficient nutrients particularly N, S and Zn nutrients in soils. An application of P in deficient soils

increased rice grain yield by between 0.78 and 3.26 t/ha and shoot -P concentration from 0.12 to 0.24%. Similarly, an application of K increased GY significantly between 0.97 t/ha and 2.76 t/ha and K- shoots concentration from 1.14 to 2.99% for the sites deficient in K. Optimum rate for fertilizers was of 10 kg P/ha and 50 kg K/ha and are recommended in deficient soils of Kilombero valley. Soils with high P and K concentration as those of Kisawasawa village do not respond to P and K fertilization and therefore application of these nutrients is not required in such soils at present. The common practice of farmers using nitrogen only is not sufficient to attain high yields in soils with multiple nutrient deficiencies. It is therefore recommended that P and K at 10 and 50 kg/ha, respectively, should be added to the fertilizer package used in the deficient soils of Kilombero district.

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