Rice Straw and Potassium Fertilization Practices on Yield of Rice (*Oryza sativa* L.) in Rakhine State

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Abstract

Field experiments were conducted to evaluate the yield response of Theehtutyin rice variety to application of rice straw and potassium fertilizer and to determine the appropriate rate of potassium for rice in Mrauk U and Kyauktaw townships, Rakhine State. Two levels of rice straw (0 and 5 t ha^{-1}) in main plot and four levels of potassium fertilizer (0, 38, 76 and 114 kg K_2O ha^{-1}) in sub plot were laid out in split-plot design with four replications. The experimental results showed that rice straw incorporation (5 t ha^{-1}) gave the higher grain yield and yield components than without rice straw. According to potassium fertilizer effects, maximum grain yield and yield components were observed from application of 114 kg K_2O ha^{-1} in Mrauk U and Kyauktaw townships. Potassium use efficiency (KUE) was not significantly affected by rice straw and different rates of potassium fertilizer. The highest potassium uptake was resulted from application of 114 kg K_2O ha^{-1}. Applied K_2O was positively correlated with grain yield and K uptake in both townships, so grain yield and K uptake were increased by progressive rates of K. Therefore the result highlighted that potassium fertilizer with rice straw should be applied at the rate of 114 kg K_2O ha^{-1} for Theehtutyin rice variety.

Key words: potassium fertilizer, rice straw, KUE, K uptake and rice yield

Introduction

Myanmar is the world's sixth-largest rice producing country and rice is the country's most important crop and is grown on over 8 million hectares, or more than half of its arable land (GRiSP 2013). The sown area of rice increased from 6.14 million hectares in 1995-1996 to 7.21 million hectares in 2015-2016 (MOAI 2016). Since rice is the major crop for both food security and economy of the country, efficient rice production is important for the country. Under long term intensive lowland rice cropping systems, the nutrient recycling of crop residues and other organic materials is important for sustainable soil fertility and crop productivity. Rice straw is often burned or removed from the field after harvest despite it is playing an important role in maintaining soil productivity if returned to the soil (Tanaka 1978). Rice straw contains a large amount of nutrients: a ton of rice straw adds 6.16 kg of nitrogen (N), 0.83 kg of phosphorus (P), 22.5 kg of potassium (K), 4.16 kg of calcium (Ca), 2.33 kg of magnesium (Mg), and 0.83 kg of sulphur (S). These values confirm the importance of straw incorporation as a mean to return such nutrients in order to reduce the cost of fertilizers (Nagarajah 1980). Moreover fertilizer has been the key input in augmenting food grain production in Myanmar as well as in the world. The major nutrients for plants are nitrogen, phosphorous and potassium. Among them, potassium (K) is an essential nutrient that affects most of the biochemical and physiological processes that influence plant growth and metabolism (Wang et al. 2013). Potassium performs important roles in enzyme activation, photosynthesis, photosynthate translocation, protein synthesis and plant water relations and is known to play an important role in the plant's ability to resist disease (Slaton et

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al. 2010).

In our country, especially in Rakhine State, the farmers mostly use nitrogenous fertilizers only and to some extent phosphate, but they use very little or no potassium fertilizer. This is due to their insufficient knowledge about balance fertilizer management of rice production and the effects of potassium on yield contributing characters and rice yield. The application of organic manure mixed up with chemical fertilizer can prove to be an excellent procedure in maintaining and improving the soil fertility, and increasing fertilizer use efficiency. Therefore the experiment was conducted to evaluate the yield response of lowland rice to rice straw and potassium fertilizer in Rakhine state, and to determine the appropriate rate of potassium fertilizer for lowland rice in the study area.

Materials and Methods

The field experiments were conducted in Mrauk U and Kyauktaw townships, Rakhine State during summer rice growing season from December 2015 to May 2016. Two levels of rice straw (0 and 5 t ha^{-1}) in main plot and four levels of potassium fertilizer (0, 38, 76 and 114 kg K_2O ha^{-1}) in sub plot were laid out in split-plot design with four replications. The tested cultivar was Theehtutyin which crop duration was 115 to 120 days. Rice straw was chopped and incorporated into the soil two weeks before transplanting. Potassium fertilizers (38, 76, 114 kg K_2O ha^{-1}) were broadcasted in 3 splits, one third of total was added as basal, one third of total at active tillering stage (25 days after transplanting, DAT), and the remaining one third of total at panicle initiation stage (45 DAT). Phosphorus fertilizer (28 kg P_2O_5 ha^{-1}) was applied as basal before transplanting and nitrogen fertilizer (87 kg N ha^{-1}) was added in 3 equal splits; one third was applied at recovery stage (7 DAT), one third at active tillering stage (25 DAT), and the remaining one third at panicle initiation stage (45 DAT). The soil sample was analyzed for some physicochemical properties at the Department of Agricultural Research (DAR). The soil of both experimental sites were sandy clay loam in texture and moderately acidic in reaction (Table 1). Seedlings were raised in nursery and then twenty-five days old seedlings were transplanted with two plants $hill^{-1}$ at the spacing of 20 cm x 15 cm. The plants were harvested at crop maturity around 120

Table 1. The physicochemical properties of experimental soil before experiment

Characteristics	Units	Mrauk U		Kyauktaw	
		Result	Rating	Result	Rating
Soil pH		5.60	Moderately Acid	5.70	Moderately Acid
Available N	mg kg^{-1}	103.00	High	102.00	High
Available P	mg kg^{-1}	5.00	Low	3.00	Low
Available K	mg kg^{-1}	59.00	Low	34.00	Low
Cation Exchange Capacity	cmol (+)kg^{-1}	4.00	Very Low	8.00	Low
Organic Matter	%	3.40	High	2.20	Medium
Soil Texture Type		Sandy Clay Loam		Sandy Clay Loam	
Sand	%	56.61		59.01	
Silt	%	21.03		19.16	
Clay	%	22.36		21.83	

Source: Soil and Plant Analysis Laboratory, Soil Science Section, Soil Science, Water Utilization and Agricultural Engineering Division, Department of Agricultural Research (DAR)

days after sowing (DAS) in both townships. The grain yield was determined from a central 5 m^2 harvested area in each plot and was adjusted to 14% moisture content. The recorded five hills were selected to assess the yield component parameters such as number of panicles $hill^{-1}$, number of spikelets $panicle^{-1}$, filled grain % and 1000 grain weight. Potassium use efficiency (KUE) was calculated by using the following formula:

$$KUE = \frac{GY_{+K} - GY_{0K}}{FK}$$

Where,

GY_{+K} = grain yield in a treatment with K application (kg ha^{-1})

GY_{0K} = grain yield in a treatment without K application (kg ha^{-1})

FK = the amount of fertilizer K applied (kg ha^{-1})

(Dobermann and Fairhurst 2000)

At harvesting stage, two hills in each plot were used as sample for plant analysis to determine potassium uptake. The following formulas were used to calculate K uptake of straw, grain and total.

$$\text{K uptake of straw (kg ha}^{-1}) = \frac{\text{K content in straw (\%)} \times \text{Dry weight of straw (kg ha}^{-1})}{100}$$

$$\text{K uptake of grain (kg ha}^{-1}) = \frac{\text{K content in grain (\%)} \times \text{Dry weight of grain (kg ha}^{-1})}{100}$$

Total K uptake (kg ha^{-1}) = K uptake of straw + K uptake of grain

(Fageria 2000)

The data were subjected to analysis of variance by using Statistix (Version 8.0) and mean data were compared by Least Significant Different (LSD) at 5% level.

Results and Discussion

Yield and yield components

The differences of mean effects of rice straw and potassium fertilization were observed in grain yield, yield components and harvest index of Theehtutyin rice variety (Table 2 and 3). Grain yields were significantly different by rice straw application in both townships. The maximum grain yield, yield components and harvest index were resulted from rice straw application in both townships because rice straw has a lot of nutrients and it may become the available forms of nutrients. Among different rates of potassium fertilizer application, the highest

Table 2. Mean effects of rice straw and potassium fertilizer on grain yield and yield components of rice in Mrauk U township during summer rice growing season, 2016

Treatments	Grain yield (t ha^{-1})	Panicles $hill^{-1}$ (no.)	Spikelets $panicle^{-1}$ (no.)	Filled grain (%)	1000-grain weight (g)	Harvest index
Rice Straw						
S_0-0 t ha^{-1}	4.27 b	11.41 a	79.25 b	67.31 b	23.41 a	0.53 b
S_1- 5 t ha^{-1}	4.79 a	11.85 a	84.47 a	70.19 a	23.93 a	0.55 a
$LSD_{0.05}$	0.24	1.36	4.84	2.02	2.41	9.74
Potassium						
K_0- K- Omission	3.48 d	9.65 c	76.03 c	65.50 b	22.56 b	0.51 d
K_1-38 kg K_2O ha^{-1}	4.30 c	11.40 b	80.32 b	68.00 b	23.71 ab	0.53 c
K_2-76 kg K_2O ha^{-1}	4.98 b	12.24 ab	84.34 a	69.00 ab	23.90 ab	0.55 b
K_3-114 kg K_2O ha^{-1}	5.38 a	13.12 a	86.75 a	72.5 a	24.50 a	0.57 a
$LSD_{0.05}$	0.26	1.28	3.38	3.65	1.87	0.01
Pr>F						
Rice Straw	0.0060	0.3753	0.0415	0.0200	0.5463	0.0052
Potassium	<0.0001	<0.0001	<0.0001	0.0070	0.2130	<0.0001
S x K	0.1332	0.3440	0.0180	0.5192	0.6436	0.0169
CV_a (%)	4.65	10.39	5.25	2.61	9.03	1.61
CV_b (%)	5.40	10.46	3.94	5.06	7.54	1.83

In each column, means having a common letter are not significantly different at LSD 5 % level.

Table 3. Mean effect of rice straw and potassium fertilizer on grain yield and yield components of rice in Kyauktaw township during summer rice growing season, 2016

Treatments	Grain yield (t ha^{-1})	Panicles hill^{-1} (no.)	Spikelets panicle^{-1} (no.)	Filled grain (%)	1000-grain weight (g)	Harvest Index
Rice Straw						
S_0-0 t ha^{-}	4.12 b	8.93 a	93.00 b	77.44 a	23.74 a	0.52 b
S_1- 5 t ha^{-1}	4.99 a	9.05 a	104.44 a	79.31 a	23.98 a	0.55 a
LSD $_{0.05}$	0.32	0.33	8.12	2.09	0.36	0.02
Potassium						
K_0- K- Omission	3.82 d	8.19 b	95.30 a	76.13 b	23.62 b	0.51 d
K_1-38 kg K_2O ha^{-1}	4.45 c	9.00 a	99.15 a	76.75 b	23.81 ab	0.53 c
K_2-76 kg K_2O ha^{-1}	4.76 b	9.39 a	100.52 a	79.38 a	24.05 a	0.55 b
K_3-114 kg K_2O ha^{-1}	5.19 a	9.39 a	99.91 a	81.25 a	23.94 ab	0.56 a
LSD $_{0.05}$	0.27	0.44	9.76	2.54	0.40	0.01
Pr>F						
Rice Straw	0.0033	0.3525	0.0207	0.0650	0.1251	0.0151
Potassium	<0.0001	<0.0001	0.6791	0.0016	0.1800	<0.0001
S x K	0.0794	0.7210	0.4965	0.4253	0.7285	0.0243
CV_a(%)	6.22	3.26	7.31	2.37	1.36	2.81
CV_b(%)	5.71	4.66	9.41	3.08	1.61	1.77

In each column, means having a common letter are not significantly different at LSD 5 % level.

grain yield, yield components and harvest index were produced by the application of 114 kg K_2O ha^{-1} in both townships. This result may be due to the effects of potassium on enzyme activation, photosynthesis, photosynthate translocation, protein synthesis and plant water relations. There was no significant interaction between rice straw and potassium fertilization in grain yield and yield components of Theehtutyin rice variety in both townships. The result indicated that potassium application on grain yield and yield components was not influenced by rice straw application. Interactions were found in harvest index in both townships and number of spikelets per panicle in Mrauk U township. The result showed that rice straw and potassium application practices increased grain yield and yield components. Hossain (2006) proved that combined application of rice straw and potassium produced significant higher grain yield than control treatment.

Potassium use efficiency (KUE)

Mean effects of rice straw on potassium use efficiency (KUE) of Theehtutyin were not significantly different in both townships (Table 4). The result indicated that rice straw application gave no significant effect on KUE in the short term. Without rice straw application (S_0) gave higher numerical KUE value than that of rice straw application (S_1) in Mrauk, but KUE of S_0 was lower than that of S_1 in Kyauktaw. The physicochemical analysis showed that organic matter content of Mrauk U was higher than that of Kyauktaw and cation exchange capacity (CEC) of Mrauk U was lower than that of Kyauktaw (Table 1). Soil with high organic matter content and low CEC could not respond rice straw application in the short term, so without rice straw application gave higher KUE in Mrauk U, but it was in constrast with Kyauktaw. Different rates of potassium fertilizer gave no significant effect on KUE in both townships. Numerically, the highest KUE was observed in application of 38 kg K_2O ha^{-1}, the values were 21.41 and 16.71 kg grain increase kg^{-1} K in Mrauk U and Kyauktaw townships, respectively. The result showed that nutrient use efficiency was high at low K fertilization (38 kg K_2O ha^{-1}) level, because any small amount of nutrient applied could give a large yield response.

Potassium uptake

Effects of rice straw and potassium on K uptake by Theehutyin in Mrauk U and Kyauktaw are presented in Table 5. The highest K uptake was resulted from 114 kg K_2O ha^{-1} with and without rice straw application in both townships. The lowest K

Table 4. Mean effect of rice straw and potassium fertilizer on potassium use efficiency (KUE) of Theehtutyin rice variety in Mrauk U and Kyauktaw townships during summer rice growing season, 2016

Treatments	KUE (kg grain increase kg^{-1} K)	
	Mrauk U	Kyauktaw
Rice Straw		
S_0-0 t ha^{-1}	16.80 a	9.15 a
S_1- 5 t ha^{-1}	12.05 a	18.27 a
LSD $_{0.05}$	9.65	13.71
Potassium		
K_0- K- Omission	-	-
K_1-38 kg K_2O ha^{-1}	21.41 a	16.71 a
K_2-76 kg K_2O ha^{-1}	19.67 a	12.37 b
K_3-114 kg K_2O ha^{-1}	16.61 a	12.06 b
LSD $_{0.05}$	6.49	4.18
Pr>F		
Rice Straw	0.1275	0.1246
Potassium	0.3010	0.0569
S x K	0.0629	0.1006
CV_a(%)	38.61	79.96
CV_b(%)	30.99	27.97

In each column, means having a common letter are not significantly different at LSD 5 % level.

Table 5. Effect of rice straw and potassium fertilizer on potassium uptake of Theehtutyin rice variety in Mrauk U and Kyauktaw townships during summer rice greowing season, 2016

Treatments		Mrauk U			Kyauktaw		
		K uptake in straw (kg ha^{-1})	K uptake in grain (kg ha^{-1})	Total K uptake (kg ha^{-1})	K uptake in straw (kg ha^{-1})	K uptake in grain (kg ha^{-1})	Total K uptake (kg ha^{-1})
S_0	K_0	61.46	15.54	77	81.90	18.00	99.90
S_0	K_1	72.83	16.86	89.69	99.07	15.90	114.97
S_0	K_2	75.95	18.68	94.63	91.46	20.98	112.44
S_0	K_3	76.72	25.51	102.23	99.41	28.28	127.69
S_1	K_0	60.61	19.3	79.91	92.74	20.16	112.9
S_1	K_1	72.42	17.52	89.94	94.95	24.64	119.59
S_1	K_2	74.2	21.15	95.35	96.30	26.59	122.89
S_1	K_3	76.28	22.61	98.89	97.76	28.35	126.11

uptake was observed in plot with no treatment at all. The resulted indicated that K uptake was increased by progressive rates of potassium, but rice straw application did not influence on K uptake in the short term. Yadav et al. (2004) also reported that K fertilization increased K content and uptake of rice.

Relationship between potassium uptake and applied potassium

Theehtutyin rice variety with and without rice straw application showed the positive relationship between K uptake and applied K_2O in both townships (Figure 1 and 2). The R^2 value revealed that the 70.60 % of degree of fitness in K uptake was accounted by the linear function of applied K_2O with and without rice straw application in Mrauk U. The regression equation explained that 67.60% of variation in K uptake was accounted by the linear function of applied K_2O in Kyauktaw. According to the simple linear regression equations, K uptake could be increased in the rate of 0.147 kg in Mrauk U and 0.165 kg in Kyauktaw at every unit (kg) of applied K_2O in both with and without rice straw application. The result indicated that K uptake was positively correlated with applied K_2O.

Conclusions

Based on the finding of this study, it can be indicated that rice straw application gave the higher grain yield than without rice straw application. Grain yield and K uptake were increased by progressive rates of potassium application. Combined application of potassium and rice straw generally produced the higher grain yield than potassium application without rice straw. Therefore the result highlighted that potassium fertilizer with rice straw should be applied at the rate of 114 kg K_2O ha^{-1} for Theehtutyin rice variety. Rice straw application should be practiced to maintain the K availability in the soil and to reduce inorganic potassium fertilizer rate.

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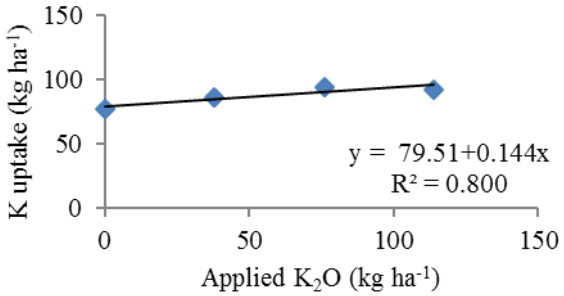
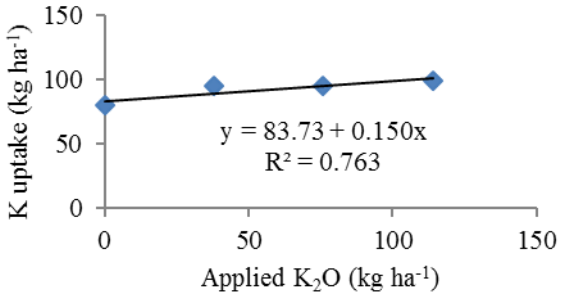
(a) Without rice straw application



(b) Rice straw application



(c) Both with and without rice straw application

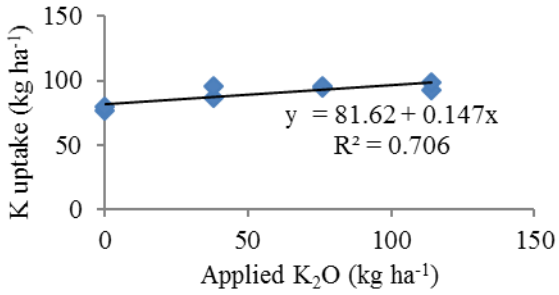


Figure 1. Relationship between K uptake and applied K_2O with and without rice straw application in Mrauk U township during summer rice growing season, 2016

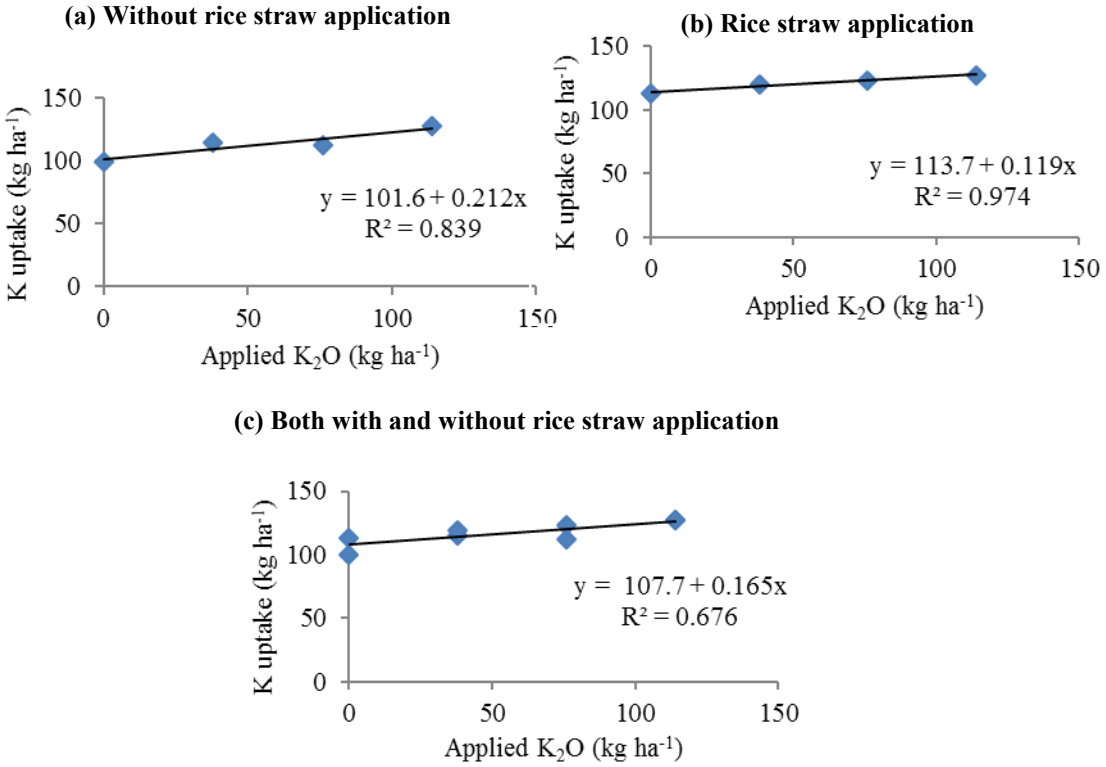


Figure 2. Relationship between K uptake and applied K_2O with and without rice straw application in Kyauktaw township during summer rice growing season, 2016

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