Towards Growing Bario Rice on Lowland Soils: A Preliminary Nitrogen and Potassium Fertilization Trial

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Abstract: A pot study was carried with the following objectives: (i) To investigate N and K uptake of Bario rice on Bekenu series (Tipik Tualemkuts), and (ii) To investigate N and K use efficiency of Bario rice on Bekenu series. Treatments evaluated were: (i) Bario rice under fertilized condition (T1), and (ii) Bario rice under unfertilized condition (T0). The experiment was conducted in a glasshouse at Universiti Putra Malaysia Bintulu Campus, Sarawak, Malaysia. Altogether 18 pots were used. The experimental design was completely randomized design (CRD) with 9 replications. Nitrogen and K were applied in the forms of urea (46 % N) and muriate of potash (60 % K_2O) at the rates of 0.52 g N g and 0.60 g K_2O per pot respectively at specific times. The fertilizers applications were done 20 and 45 days after seeding (for T1 only). However, P was applied to T1 pots only in the form of Christmas Island Rock Phosphate (36 % P_2O_5) at a rate of 0.54 g P_2O_5 per pot. At 65 days after planting, the Bario rice plants were sampled and partitioned into roots and stem. Their dry weight, N, and K concentrations determined using standard procedures. Soil sampling was done before and after fertilization stages. Soil total N was determined using the Kjeldahl method while exchangeable K, Ca, Na, and Mg were extracted using the double acid method and their concentrations determined using atomic absorption spectrophotometry. Dry ashing method was used for the determination of K, Ca, Na, and Mg concentrations in plant tissues while the Kjeldahl method was used to determine total N in plant tissues. The concentrations multiplied by the oven dried weight of roots and stem provided N, K, Ca, Na, and Mg uptake in these plant parts. The N and K use efficiency were then calculated using the subtraction method. With the exception of Ca, urea and KCl (MOP) application significantly increased soil N, K, Mg, and Na concentrations. Total dry weight for both stem and roots showed no significant difference under T1 and T0. Except for Mg concentration in stem and roots, K concentration in stem and that of N in roots were significantly higher under T1 than under T0. The other comparisons showed no significant difference. Due to N and K fertilization, there was significant increase in plant height and number of panicles under T1 compared to T0. Nitrogen, K, Na, and Mg uptake in stem were significantly higher for T1 than T0. However, those of roots were not significantly different. The overall N and K use-efficiency of the Bario rice were 9.90 % and 4.23 % respectively, and were considered low, indicating that rice grown within the time frame of this study did not efficiently utilize these nutrients. This was partly attributed to low N and K recovery during reduced condition and low organic matter status of Bekenu series as Bario rice is noted for being cultivated organically. Additionally, slow adaptation to inorganic fertilizers and sudden climatic change involved in this study cannot be ruled out as one of the reasons for the low efficiency because the rice is traditionally cultivated in the highlands of Sarawak, Malaysia. However, with appropriate fertilization and soil maintenance (through further research), Bekenu series could be used for Bario rice production. Probably supplementing inorganic fertilizers with organic ones may help to improve growth and development of this rice on Bekenu series. Future studies may consider mimicking or modifying the environment to suit Bario rice growth and development at lower elevations. Certainly, the quality of Bario rice at lower elevations should also be considered in future fertilization programmes or trials.

Key word: Bario rice, fertilizer trial, nitrogen, potassium, rice, Malaysia

INTRODUCTION

Rice is one of the most important cereal crops in the world and ranks second after wheat. The continuous growth in world rice production has further elevated its eminence as a staple, with importance equal to that of wheat. In many areas of the developing world, rice is gaining popularity as a preferred source of

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caloric supply. For instance rice covers about 148 million hectares of the earth surface and the production has been estimated to be 522 tons in the world [1]. On an average basis, rice produces a higher grain yield than wheat or maize and can support more people per hectare of land.

In Malaysia, the area of rice production is not sufficient; as a result, rice such as Bario is grown in the highlands of Sarawak. Bario rice is produced by the Kelabit farmers in Sarawak. Bario Rice is regarded by the 'Orang Ulu' tribe and natives as the finest and best rice from the highlands of Sarawak. It is grown on cool climates at an elevation above 1,200 meters. According to the natives, the rice is only eaten by the Longhouse Chief on special occasion. Bario rice has long been regarded as one of the finest rice grains of the world. It is famous for its soft texture, fine and elongated grains with mild aromas and splendid taste. It is home-grown rice, planted and harvested entirely by hand using old and traditional methods. In the fertile valleys of the highlands rice is grown at 1200 meters above the sea level and irrigated by the cool and clean mountain streams. Bario rice is produced without the usage of pesticides and chemical fertilizers, probably due to logistics of transporting these materials to the highlands. Even if the pesticides and fertilizers get there, they are expensive for the local farmers to afford. Therefore Bario rice has all the attributes of organic rice with the added flavour and distinguished taste derived from the cool, pristine and unpolluted environments where it is grown. Bario rice is from the Adan variety and the market price ranges from RM 8 (US$ 2.30) to RM 9 (US$3.00) per kilogram. Even though the Bario rice is popular with good price in Sarawak, the optimum yield (potential yield) has not been attained. One of the reasons could be lack of adequate use of nutrients such as N, P, and K. Besides, the cultivation of this rice has not been tested on lowland acid soils such as Bekenu series commonly found in the tropics to enable wide cultivation to meet the current demand of the rice.

Since the rice cultivar is commonly planted in high hilly areas, this experiment will exposed it to the local Bintulu, Sarawak soil type such as the Bekenu series. The Bekenu series is a member of the Bekenu family which is fine *loamy, siliceous, isohyperthermic, red-yellow to yellow Tipik Tualemkuts* [2]. It typifies the family and is developed over mixed sedimentary rocks. Soils of the Bekenu series are defined as being characterized by their deep, well drained profiles with brownish yellow to yellow subsoil colours dominating the subsoil. These soils have an argilic horizon with fine sandy clay loam textures and ECECclay of less than 24 cmol (+) kg^{-1} clay in all subhorizons (between 25 to 100 cm depth). They have weak medium to coarse subangular blocky and consistence is friable. In terms of suitability for agriculture, the Bekenu series has low fertility status and the terrain on which these soils occur are the main limiting factors for the use of these soils. However, with proper fertilization and soil conservation measures, a wide range of crops such as upland rice could be cultivated on these soils.

The objectives of this study were: (i) To investigate N and K uptake of Bario rice on Bekenu series, and (ii) To investigate N and K use-efficiency of Bario rice on Bekenu series.

MATERIALS AND METHODS

The experiment was a pot study and conducted in a glasshouse at the Universiti Putra Malaysia Bintulu Campus, Sarawak. The type of soil used in this study was Bekenu series. The test crop in this study was Bario rice. Based on the soils' bulk density, plastic pots measuring 36 cm (height) x 30 cm (diameter) were filled with soil samples until the bulk density of this soil was attained. The soil in the plastic pots were flooded to 5 cm water above the soil surface and the rice seeds seeded at a rate equivalent to 25 kg/ha (current seeding rate). It should be noted that for a good establishment, seeds were soaked for 24 hours in sacks. Planting involved two distinct operations – dibbling plant holes and sowing the seed. Dibbling was done with a staff or dibble – stick which was flared out slightly towards the base. The dibble – stick was dibbled into the soil and removed with a slight twisting action usually leaving well – formed planting holes 2 cm in diameter. The depth of the planting holes ranged from 2 – 4 cm. Sowing was done by hand – broadcast and regulated by the number of seeds per throw. Seeds were sown directly in each planting hole. The planting holes were partially covered by loose soil from the surface so to allow quick emergence of the seeds. There were 12 seeds per pot.

Before the start of the experiment, the soil was analyzed for bulk density, pH, total N, exchangeable K, Mg, Ca, total organic carbon, and cation exchange capacity (CEC). In this study, the coring method was used to obtain the bulk density of the soil [3]. The bulk density of the Bekenu series was 1.25 g/cm^3 and was typical of this soil series. To determine the pH in water and in 1 N KCl, a pH meter and pH buffer solutions (pH 4 and pH 7) were used. Ten grams of soil samples were used in determining pH in water and 1 N KCl (soil to water or 1 N KCl of 1:2). The pH of the soil in water

was 4.5 while that in 1 N KCl, was 3.5 and they are consistent with the pH of acid soils of Malaysia.

Total N was determined using micro-Kjeldahl method [4]. About 0.5 gram of soil, stem and roots were separately weighed into 50 mL Kjeldahl digestion tubes and treated with 5 mL concentrated sulphuric acid and one tablet of Kjeldahl catalyst (mixture of high selenium and sodium sulphate anhydrous) put in each tube. The samples were shaken and allowed to equilibrate for 30 minutes after which they were digested on a digestion block in a fume chamber. The samples were initially heated at 180 ^{o}C for 1 hour and then to 320 ^{o}C for 5 hours until samples became colourless, and they were then allowed to cool down. Afterwards, the samples were transferred into 50 mL volumetric flasks, diluted to volume using distilled water, and then filtered through Whatman filter paper number 2. Ten mL of the filtrates were distilled with 10 mL of 40 % NaOH and the ammonium collected into 50 mL Erlenmeyer flask containing 10 mL of 2 % boric acid-indicator mixture (bromocresol green-methyl red). Total N was determined by titrating the distillates with 0.01 M HCl. The total was found to be 0.25 % and typical of Bekenu series.

The double acid method [3] was used to extract the exchangeable K, Ca, and Mg in soil. Forty mL of 0.05 M HCl:0.025 M H_2SO_4 and another 40 mL of distilled water were separately added to 10 g of soil samples in plastic vials. The samples in the plastic vials were shaken for 10 minutes in an orbital shaker at 180 rpm. The samples were then filtered into new sets of plastic vials and filtered using Whatman paper number 2. The solutions were then analyzed for the exchangeable K, Ca, and Mg using the Atomic Absorption Spectrophotometry (AAS) and their concentrations were 6.82, 6.54, and 35.48 ppm. The K and Ca contents were typical of Bekenu series but that of Mg looks high.

Dry ashing (single dry ashing) [5] was adopted for the extraction of K, Ca, Mg, and Na in the plant tissues. Some samples of stem and roots were initially oven dried for 24 hours at a temperature of 60 ^{o}C after which they were cooled in a desicator and 0.5 g weighed into crucibles and placed in a muffle furnace and initially ashed at 300 ^{o}C for 1 hour. The temperature was raised to 520 ^{o}C for 5 hours. Few drops of distilled water were added to the samples, followed by 2 mL concentrated HCl. Samples were evaporated to dryness in a fume chamber. Ten mL of 20 % HNO_3 was added to the samples and heated on a hot plate in a fume chamber

for 1 hour. The samples were filtered through Whatman filter paper number 2 into 100 mL volumetric flasks, and diluted to volume. The filtrates were analyzed for K, Ca, Mg, and Na using AAS.

Cation exchange capacity of the soil samples was determined using the ammonium acetate (leaching) method [5]. Ten gram of each soil samples were weighed into leaching tubes covered with broth at the base and Whatman filter paper number 2 at both ends. The soil samples were leached with 1 M NH$_4$OAc for 6 hours. The samples were then washed with 95 % of ethanol and the ethanol discarded after collection. The soils were then leached with 100 mL of 0.1 M K$_2$SO$_4$ and the leachate collected in 100 mL volumetric and made up to volume. Ten mL of the samples were pipetted into distillation apparatus and 10 mL of 40 % NaOH added. The distillates were distilled and collected in 10 mL of 2 % boric acid-indicator solution until 50 mL conical flask containing the distillate was twice the original volume (20 mL). The colour changed from purple to green during distillation. The distillates were then titrated with 0.01 M HCl until the colour changed from green to purple (end point). The CEC was 10.7 cmol/kg soil and typical of Bekenu series.

The fertilizer rate (Table 1) of 50 N kg/ha, 40 P kg/ha and 30 K kg/ha for the Bario rice variety was followed (recommendation of Semengok Agriculture Research Centre, Kuching, Malaysia). The fertilizers used were urea (46% N), Christmas Island Rock Phosphate (36% P$_2$O$_5$) and Muriate of Potash (60% K$_2$O).

Table 1: Split fertilizer application

Application	Days after seeding
1st application (1/3)	20
2nd application (1/3)	45
3rd application (1/3)	75

Table 2: Effect of fertilized (T1) and unfertilized (T0) conditions on CEC and pH

	Treatment	Value
(a)	CEC (cmol/kg) (T0)	11.56[a]
	(T1)	12.56[a]
(b)	pH in KCl	
	(T1)	4.18[b]
(c)	pH in Water	
	(T1)	4.99[b]

Note: Same alphabet within column indicates insignificant difference between treatment means using independent t-test at p≤ 0.05.

Table 3: Total N, exchangeable K, Ca, Na, and Mg in soil under fertilized and unfertilized conditions

	Without Fertilizer (T0)					With Fertilizer (T1)				
	N	K	Ca	Na	Mg	N	K	Ca	Na	Mg
	%	-------------------------ppm-----------------------				%	-------------------------ppm-----------------------			
	0.44[a]	38.19[a]	73.86[a]	28.38[a]	20.31[a]	0.62[b]	117.27[b]	89.22[a]	33.24[b]	22.55[b]

Note: Same alphabet within row indicates insignificant difference between treatment means using independent t-test at $p \leq 0.05$.

Table 4: Nitrogen, K, Ca, Mg, and Na concentrations in roots and stem of Bario rice under fertilized and unfertilized conditions

Treatment	N	K	Ca	Na	Mg
	-------------------------------------%---------------------------------				
(a) Roots					
(T1)	0.70[b]	0.17[a]	0.01[a]	0.06[a]	0.06[b]
(b) Stem					
(T1)	1.59[a]	1.19[b]	0.07[a]	0.03[a]	0.06[b]

Note: Same alphabet within column indicates insignificant difference between treatment means using independent t-test at $p \leq 0.05$.

Table 5: Dry weight (DW), N, K, Ca, Mg, and Na uptake in roots and stem under fertilized and unfertilized conditions

	Without Fertilizer (T0)						With Fertilizer (T1)					
Parts	DW	N	K	Ca	Na	Mg	DW	N	K	Ca	Na	Mg
	------------------------- (g) -----------------------						----------------------------- (g) ---------------------------					
Roots	3.23[a]	0.02[a]	0.01[a]	0.0001[a]	0.003[a]	0.002[a]	4.19[a]	0.04[a]	0.01[a]	0.0003[a]	0.003[a]	0.002[a]
Stems	1.08[a]	0.014[a]	0.01[a]	0.001[a]	0.0004[a]	0.001[a]	2.68[a]	0.04[b]	0.03[b]	0.002[a]	0.001[b]	0.002[b]
Total	4.31	0.03	0.02	0.0011	0.0034	0.003	6.87	0.08	0.04	0.0023	0.004	0.004

Note: Same alphabet within row indicates insignificant difference between treatment means using independent t-test at $p \leq 0.05$.

Table 6: Nitrogen and K use efficiency in roots and stem of Bario rice

Treatments	N	K
	----------------------------%---------------	
Roots	4.466	0.067
Stem	5.437	4.167
Total	9.903	4.234

The plants were monitored for 65 days. After 65 days, soil samples were taken and analyzed for N, K, Ca, Mg, Na, organic matter, pH, and CEC. Nitrogen, and K uptake and yield of the rice variety were determined. At 65 days after planting, the plants were harvested and partitioned into roots and stem. Standard procedures were used to dry these parts, and determination of their dry weight.

The concentrations of N and K in the plant parts multiplied by their dry matter gave the amount of N and K taken up by the plant parts. Nitrogen and K use-efficiency were calculated using the subtraction method [6]. Nitrogen and K use efficiency was calculated using the formula:

% N use efficiency=

$$\frac{(\text{Total N uptake in fertilized plots} - \text{Total N uptake in unfertilized plots} \times 00\%}{\text{Total amount of N fertilizer applied}}$$

The experimental design was completely randomized design with nine replications. Data was analyzed statistically by independent and paired t-test to detect treatment effect. The statistical software used was the Statistical Analysis System (SAS) version 9.1 [7].

RESULTS AND DISCUSSION

The CEC and pH after harvest under fertilized and unfertilized conditions are presented in Table 2. The treatment mean of the CEC for without fertilizer (T0) was 11.56 cmol (+)/kg while that of with fertilizer (T1) was 12.56 cmol (+)/kg. The treatment mean of T0 for pH in KCl, was 3.98 while that of T1 was 4.18. As for the treatment mean of T0 for pH in water, it was 4.82 and that of T1 was 4.99. Regardless of treatment, CEC and pH values were typical of Bekenu series. The outcome of the statistical comparisons of treatment means (Table 2) were: (i) CEC in soil for T0 and CEC in soil for T1 – no significant difference, (ii) pH in KCl
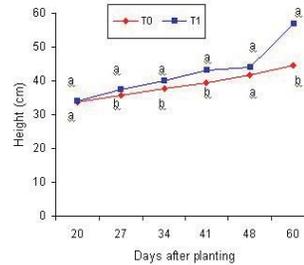
for T0 and pH in KCl for T1 – significant difference, and (iii) pH in water for T0 and pH in water for T1 – significant difference.

The total N, exchangeable K, Ca, Na, and Mg in soil with and without fertilization are shown in Table 3. The treatment mean of T0 for total N was 0.44 % and that of T1 was 0.62 %. The treatment means of T0 for K, Ca, Na, and Mg were 38.19, 73.86, 28.38, and 20.31 ppm respectively while those of T1 for K, Ca, Na, and Mg were 117.27, 89.22, 33.24, and 22.55 ppm respectively. The outcome of the statistical comparisons of treatment means (Table 3) were: (i) Total N in soil for T0 and T1 – significant increase, (ii) Exchangeable K in soil for T0 and T1 – significant increase, (iii) Exchangeable Ca in soil for T0 and T1 – no significant increase, (iv) Exchangeable Na in soil for T0 and T1 – significant increase, and (v) Exchangeable Mg in soil for T0 and T1 – significant increase.

The N, K, Ca, Mg, and Na concentrations in Bario rice roots and stem unfertilized and fertilized conditions are presented in Table 4. For roots, the treatment means of T0 for N, K, Ca, Na, and Mg were 0.52, 0.15, 0.004, 0.08, and 0.05 % respectively while that of T1 for N, K, Ca, Na, and Mg were 0.70, 0.17, 0.01, 0.06, and 0.06 % respectively. As for stem, the treatment means of T0 for N, K, Ca, Na, and Mg were 1.34, 0.74, 0.11, 0.04, and 0.05 % respectively while that of T1 for N, K, Ca, Na, and Mg were 1.59, 1.19, 0.07, 0.03, and 0.06 % respectively. The outcome of the statistical comparison of treatment means (Table 4) were: (i) Nutrient concentrations in roots for T0 and T1 conditions – no significant increase in K, Ca, and Na but significant increase for N and Mg, and (ii) Nutrient concentrations in stem for T0 and T1 conditions – no significant increase in N, Ca, and Na but significant increase for K and Mg.
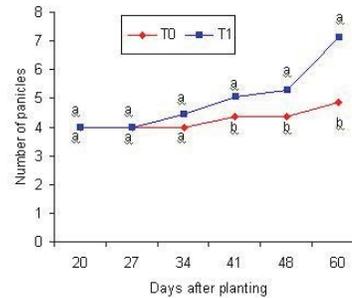
The average height and panicles of Bario rice per pot from Day 20 to Day 60 are presented in Figures 1 and 2. The average height of paddy for T0 in ascending order (Day 20 to Day 60) were 33.61, 35.67, 37.61, 39.33, 41.61, and 44.44 cm while those of T1 in ascending order (Day 20 to Day 60) were 33.94, 37.56, 39.94, 43.22, 44.11, and 56.89 cm. The average numbers of panicles of the paddy for T0 from Day 20 to Day 60 were 4, 4, 4, 4.38, 4.38, and 4.88. The average numbers of panicles of the paddy for T1 from Day 20 to Day 60 were 4, 4, 4.44, 5.05, 5.29, and 7.11. The results of the comparison of treatment means were: (i) Height of Bario rice for T0 and that of T1 – no significant increase on Day 20 and Day 48 and significant increase on Days 27, 34, 41, and 60, and (ii) Number of panicles of Bario rice for T0 and that of T1 – no significant

increase from Day 20 to Day 34 and significant increase from Day 41 to Day 60.

Note: Same alphabet indicates no significant difference between treatment means using independent t-test at $p \le 0.05$.

Fig. 1: Effect of fertilized and unfertilized conditions on Barice rice height with time

Note: Same alphabet indicates no significant difference between treatment means using paired t-test at $p \le 0.05$.

Fig. 2: Effect of fertilized and unfertilized conditions on Barice rice panicles with time

Fig. 3: Growth of fertilized (T1) and unfertilized (T0) Bario rice

Fig. 1 shows an increase in the height of Bario rice from Day 20 to Day 60 for both treatments (T0 and T1). Also noticeable is that the plant height of T1 was higher

than T0 starting from Day 27 until Day 60. As for Fig. 2, it shows a constant number of panicles from Day 20 to Day 34 for T0 and then gradually increased with time from Day 34 to Day 60 while for T1, a constant number of panicles from Day 20 to Day 27 followed by a gradual increased with time from Day 27 to Day 48 and a sharp increased from Day 48 to Day 60 can be seen in Fig. 2. Fig. 3 shows the height and number of panicles of the fertilized and unfertilized Bario rice. The growth of the fertilized plants was clearly better than those of the unfertilized plants.

The dry weight of Bario rice roots and stem for T0 and T1 are presented in Table 5. The total dry weight (roots and stem) of T0 and T1 were 4.31 g and 6.87 g respectively. In terms of parts, the dry weight production (roots and stem) regardless of treatments was not significant. The total nutrients uptake for T0 and T1 respectively were: N = 0.03 g and 0.08 g; K = 0.02 g and 0.04 g; Ca = 0.001 g and 0.002 g; Na = 0.003 g and 0.004 g; and Mg = 0.003 g and 0.004 g. Irrespective of treatment, K and Ca distribution was higher in the stems than in the roots. In the case of Na, the distribution was higher in roots than in stem. As for N, the distribution was higher in roots than in stem for T0. In the case of T1, it was higher in stem than in roots. For Mg, the distribution was higher in roots than stem for T0 while for T1, the distribution in roots and stem was similar. The results of the statistical comparisons of treatment means (Table 5) were: (i) T0 and T1 – no significant increase in dry weight (DW), N, K, Ca, Na, and Mg uptake in roots, and (ii) No significant increase in dry weight (DW), and Ca uptake but significant increase in N, K, Na, and Mg uptake in stem.

The results of the N and K use efficiency in roots and stem are shown in Table 6. For roots, the percentage for N was 4.466 and K was 0.067 while for stem, the percentage for N was 5.437 and K was 4.167. The overall N and K use efficiencies of the Bario rice were 9.90 % and 4.23 % respectively.

The insignificant difference between the CEC of T0 and T1 at harvest suggests that fertilization did not affect the exchange property of the soil within the time frame of this study (Table 2). This observation was expected as organic matter that usually affects soil CEC was not included in this study and no leaf decomposition in the experimental pots as the plant grew was observed. However, the pH of T1 in both water and KCl were greater than those of T0 (Table 2) probably due to the addition of fertilizers particularly urea which is known for increasing soil pH rapidly at the soil microsites [8]. Anhydrous ammonia, urea, diammonium phosphate, and nitrogen solutions, when first applied, greatly but temporarily increase soil pH in the zone of application [9].

The significant increase in soil N, K, Mg, and Na concentrations (Table 3) for the fertilized condition (T1) could be attributed to the addition of urea and KCl (MOP). This finding was consistent with that of Nand [10] who observed that the patterns of the availability of N and K were affected by continuous fertilizer use.

The general insignificant difference in nutrient concentrations in roots and stem (Table 4) may be ascribed to dilution effect [11, 12]. Lack of significant effect on N uptake may be partly due to ammonia volatilization and denitrification under reduced condition or under submerged conditions of rice [13, 14]. Upon application, urea-N changes rapidly to NH_4^-N and therefore is readily available to plants on application to the soil. Urea presents another problem, in that when it is surface-applied, significant quantities of nitrogen as ammonia may be lost through volatilization which cause low N uptake in plants [13, 14]. This occurs because the urea dissolves, be in contact with the soil for conversion to volatile nitrogen, and easily escapes to the atmosphere due to its proximity to the soil surface [13, 14].

Although there was general increase in plant height and number of panicles with time irrespective treatments, the significant increase in these variables with time (Figs. 1 to 3) under the fertilized condition (T1) compared with the unfertilized condition (T0) to fertilization with time could be partly associated with K and N fertilization.

There was no significant difference between root dry weight and N, K, Ca, Na, and Mg under T0 and T1. In the case of stem, the difference in dry weight of the treatment was not significant but in terms of uptake, except for Ca, N, K, Na, and Mg uptake under T1 were statistically higher than T0. Obviously, addition of urea and KCl fertilizers explains the higher uptake of N and K in the stem under the fertilized condition compared to the unfertilized condition. Different rates of N and K applied to rice plant under greenhouse conditions significantly increased the uptake of macro and micro-nutrients in rice grain [15].

Regardless of treatment, the low percentages of N and K indicate that the N and K nutrient uptake by the plants even though significant in stem, the general nutrient use by Bario rice on Bekenu series was low or inefficient. The low fertility status and the terrain on which these soils occur could be some of the limiting factors for the use of these soils. However, with proper addition of organic fertilizers as supplement of

inorganic fertilizers and soil conservation measures, the N and K use efficiency may be improved.

CONCLUSION

Application of N and K fertilizers significantly increased N, K, Mg, and Na accumulation in Bekenu series soil. Roots and stem dry weight of Bario rice showed no significant difference under T0 and T1. Addition urea and MOP had significant effect on N and K uptake in stem. However, the N and K use-efficiency (10 % for N and 4 % for K) of Bario rice on Bekenu series was low.

As the results showed inefficient nutrient use, series of trials on Bekenu series on the interaction between inorganic and organic fertilizers (e.g. compost) should be carried out. This is essential because Bario rice seems to grow well under organic fertilization. Probably supplementing inorganic fertilizers with organic fertilizers may help in good growth and development of Bario rice on Bekenu series since it may be difficult and expensive to mimic the climatic conditions under which Bario rice grows well.

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