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Effects of Magnesium Fertilization on Rice Yield, Magnesium and Potassium Uptake by Rice at Variable Applied Potassium Levels

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A greenhouse experiment was conducted at University Putra Malaysia to evaluate the effects of magnesium (Mg) fertilization on rice yield, Mg and potassium (K) uptake by rice at variable applied potassium levels. Two soils (Guar and Hutan series), three Mg rates (0, 10 and 20 kg Mg ha^{-1}) and three K rates (0, 20 and 40 kg K_2O ha^{-1}) were used in the study. Grain and straw yields, total Mg and total K uptakes were significantly higher in Guar series compared to Hutan series. Potassium effect was not significant on any of the parameters. Magnesium fertilization increased grain and straw yields, Mg and K uptakes significantly in both the soils. Regression analysis indicated that estimated grain and straw yield responses to added Mg were linear in nature in Guar series while these were quadratic in nature in Hutan series. Similar trends were found for total Mg and K uptakes. The findings of this study indicate that Mg fertilization should be done in Mg deficient soils to increase rice yield.

Key words: Magnesium, Rice, Potassium.

Introduction

Potassium is a primary essential element for all plants including rice and its requirement for rice is high (Sahrawat 2000). Rice plant removes about 19 kg K for production of 1 tonne rough rice including straw (De Datta 1981). Although wetland rice soils are well supplied with K, cropping without K fertilization deplete K content of soil due to high amount of K removal by rice plant and as a result rice crop suffers from K deficiency (BRRI 1966; MARDI 1992, 1993). Magnesium is another essential element for all plants including rice. A rice crop removes about 4 kg Mg for the production of 1 tonne rough rice including straw (De Datta 1981). Low supply of Mg was reported to depress rice yield and cause iron deficiency syndrome on strongly acid soils (Ponnamperuma and Deturck 1993).

The largest rice growing area in Malaysia is located in Muda Irrigation Scheme, Kedah that covers an area of about 95,000 ha. Recent studies showed that there is a tendency of yield decline in many sites of this area due to Mg deficiency (Samy *et al* 1992). Investigations have shown that soils are dificient in Mg in many locations of this irrigation scheme (Choudhury and Khanif 1998, 2000). Jones *et al* (1982) reported that high plant concentration of K restricted Mg uptake. Similar problems may be encountered in Malaysian conditions. As some Malaysian rice soils are deficient in Mg, it is essential to apply Mg in order to meet crop requirement. But the magnitude of Mg response may vary at different levels of applied K. With this view in mind, the present study was undertaken to evaluate the effects of Mg fertilization on rice yield, magnesium and potassium uptake by rice at variable applied K levels.

Materials and Methods

Soils were collected from rice growing areas under Muda Irrigation Scheme, Kedah, about 500 km north of Kuala Lumpur, Malaysia. Two soils (Guar and Hutan series) were used in the study. Parent materials of Guar and Hutan series are marine and riverine alluvium, respectively. The taxonomic class of Guar series is Typic sulfaquept, very fine clayey, mixed, isohyperthermic, brown. On the otherhand the taxonomic class of Hutan series is Aeric Plinthic kandiaqualt, fine clayey, kaolinitic, isohyperthermic, pallid (Paramananthan 1998). Soil samples were collected from 0-15 cm depth. The soils were air dried, ground and sieved through 2-mm sieve. Soils were analysed for organic carbon, pH, cation exchange capacity (CEC), total N, available P, exchangeable K, Mg and Ca, available Zn and Cu. Properties of the soils are given in Table 1. Organic carbon was analysed by potassium dichromate and H_2SO_4 digestion method (Walkley and Black 1934) and

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Table 1
Selected properties of the soils under study

Properties	Guar	Hutan
Organic matter (%)	5.61	1.82
pH	3.2	3.6
Cation exchange capacity (cmol kg^{-1})	13.48	7.15
Total N (%)	0.16	0.07
Available P (mg kg^{-1})	6.8	31.1
Exchangeable K (cmol kg^{-1})	0.32	0.13
Exchangeable Mg (cmol kg^{-1})	0.29	0.09
Exchangeable Ca (cmol kg^{-1})	2.09	1.93
Available Zn (mg kg^{-1})	1.58	2.99
Available Cu (mg kg^{-1})	0.15	3.10

organic matter was estimated by multiplying the value with 1.732. Soil pH (measured in H_2O) was measured by glass electrode (Peech 1965). Total N was determined by sulphuric-salicylic acid digestion method (Bremner and Mulvaney 1982). Available P was determined by NH_4F-HC1 extraction method (Bray and Kurtz 1945). Cation exchange capacity, exchangeable K, Mg and Ca were determined by ammonium acetate extraction method at pH 7 (Schollenberger and Simon 1945). Available Zn and Cu were analysed by 0.05 *N* HC1 extraction method (Ponnamperuma *et al* 1981).

The experiment was three factorial (soil, Mg rate and K rate). Two soils (Guar and Hutan), three Mg rates (0, 10 and 20 kg Mg ha^{-1}) and three K rates (0, 20 and 40 kg K_2O ha^{-1}) were used in the experiment. The experiment was laid out in randomised complete block design (RCBD) with four replications. The soils used for the study were collected from the plough layer of the field and filled into plastic pots of 15-liter capacity to 10 cm below the brim of the container. The soils were flooded and pre-incubated for three weeks to stabilise their physico-chemical properties before seed sowing. Sprouted rice seeds of variety MR185 were sown. The number of seeds needed per pot was calculated on the basis of surface area of the pot and a sowing rate of 40 kg ha^{-1}. Ten sprouted seeds were equally spaced in the puddle soil of each pot.

Nitrogen was applied as urea to each pot using a single rate (120 kg N ha^{-1}) in three splits (1/2 as basal + 1/4 at active tillering stage + 1/4 at panicle initiation stage). Phosphorus was applied as triple superphosphate (TSP) to each pot using a single rate (30 kg P_2O_5 ha^{-1}). Magnesium was applied as magnesium sulphate ($MgSO_4$ $7H_2O$) according to treatments (0, 10 and 20 kg Mg ha^{-1}). Potassium was applied as muriate of potash (MOP) according to treatments (0, 20 and 40 kg K_2O ha^{-1}). Phosphorus, magnesium and potassium were applied as basal. Nitrogen and magnesium were applied in solution form. The amount of fertilizers was calculated on the basis of soil surface area of each pot. Rice crop was harvested at maturity. Grain and straw weights (gram per pot) were recorded. Grain and straw yields were calculated as t ha^{-1} considering the surface area of each pot. About 10 g of representative grain and straw samples were ground to pass through a 1-mm sieve and were kept in plastic containers for chemical analysis. Grain and straw samples were digested with H_2SO_4 and H_2O_2 (Thomas *et al* 1967). After digestion, Mg and K contents of the samples were measured by atomic absorption spectrophotometer. Magnesium uptake by rice grain and straw were calculated by multiplying yield data with magnesium content in grain and straw, respectively. Total Mg uptake was obtained from the summation of Mg uptake by grain and straw. Similarly total K uptake was calculated.

The data were analysed for analysis of variance (ANOVA) and the means were compared using Duncan's multiple range test (DMRT) where the F-test was significant. Regression analysis were done for Mg rates versus grain and straw yields, Mg and K uptakes. As only three rates of Mg were used in the study, four replicated values of yield and uptake data were used for regression analysis. All the analysis were done following Statistical Analysis System (SAS Institute Inc 1987).

Results and Discussion

Grain and straw yields. Effects of soil and Mg on grain and straw yields (t ha^{-1}) were significant (Table 2 & 3), whereas K effect was not significant. Interaction effect of soil and Mg was significant. Grain and straw yields were significantly higher in Guar series over Hutan series. In Guar series, grain and straw yields increased significantly due to Mg fertilization at 10 kg Mg ha^{-1}, beyond this rate yield increases were not significant although there were slight increases in yields. In Hutan series, grain and straw yields increased significantly due to Mg fertilization at 10 kg Mg ha^{-1}, beyond this rate Mg effect was not significant although there were slight decreases in yields. Regression analysis indicate that grain and straw yields increases to added Mg were linear in Guar series while these were quadratic in Hutan series (Table 6).

Higher grain yield in Guar series compared to Hutan was attributed to the difference in fertility status of the soils (Table 1). Guar series had higher organic matter content, cation exchange capacity, total N and exchangeable Mg, which might contributed in higher yield in this soil. Yield variation due to soil fertility was observed in previous investigations (MARDI 1988, 1993). The increase in grain yield due to magnesium fertilization in both the soils was due to Mg deficiency in the soils. Magnesium content in both the soils was below the

Table 2

Effect of Mg on grain yield of rice in two soils under variable applied K levels

Soil(s)	Mg rate (kg ha^{-1})	K rate (kg ha^{-1})			S*Mg-mean[1]	Soil-mean
		0	20	40		
		Grain yield (t ha^{-1})				
Guar	0	4.46	5.00	3.55	4.34b	-
	10	6.41	6.29	6.75	6.48a	-
	20	6.20	6.71	6.99	6.63a	5.82a
Hutan	0	1.55	1.45	1.74	1.58d	-
	10	2.47	2.61	2.51	1.53c	-
	20	2.02	2.13	2.63	2.26c	2.12b
K-mean[2]		3.85	4.03	4.03	-	-

[1]Interaction effect of S and Mg was significnt; [2]Effect of K was not significant; Means followed by a common letter in a column are not significantly different at 5% level by DMRT.

Table 3

Effect of Mg on straw yield of rice in two soils under variable applied K levels

Soil(s)	Mg rate (kg ha^{-1})	K rate (kg ha^{-1})			S*Mg-mean[1]	Soil-mean
		0	20	40		
		Straw yield (t ha^{-1})				
Guar	0	4.94	5.55	3.94	4.81b	-
	10	7.12	6.98	7.50	7.20a	-
	20	6.88	7.45	7.76	7.36a	6.46a
Hutan	0	1.72	1.61	1.93	1.75d	-
	10	2.71	2.90	2.79	2.80c	-
	20	2.25	2.37	2.92	2.51c	2.35b
K-mean[2]		4.27	4.48	4.47	-	-

[1]Interaction effect of S and Mg was significnt; [2]Effect of K was not significant; Means followed by a common letter in a column are not significantly different at 5% level by DMRT.

critical deficiency level of 0.40 cmol kg^{-1} (Sattar and Rahman 1987). The increases in grain and straw yields due to Mg fertilization are in agreement with previous findings (Choudhury and Khanif 2001; Vijayalaksmi and Mathan 1994; Sahrawat *et al* 1999).

Plant Mg uptake. Effects of soil and Mg on total Mg uptake (kg ha^{-1}) was significant (Table 4), whereas K effect was not significant. Interaction effect of soil and Mg was significant. Magnesium uptake was significantly higher in Guar series over Hutan series. Magnesium fertilization increased total Mg uptake significantly up to 20 kg Mg ha^{-1} in Guar series while Mg effect was significant up to 10 kg Mg ha^{-1} in Hutan series. Regression analysis indicated that total Mg uptake increased linearly due to Mg fertilization in Guar series while its

Table 4

Effect of Mg on total Mg uptake by rice in two soils under variable applied K levels

Soil(s)	Mg rate (kg ha^{-1})	K rate (kg ha^{-1})			S*Mg-mean[1]	Soil-mean
		0	20	40		
		Total Mg uptake (kg ha^{-1})				
Guar	0	5.94	7.19	5.12	6.08c	-
	10	11.70	10.52	11.12	11.11b	-
	20	13.06	12.63	12.76	12.82a	10.00a
Hutan	0	2.09	1.78	2.15	2.01e	-
	10	3.94	3.54	3.54	3.67d	-
	20	3.70	3.28	4.25	3.74d	3.14b
K-mean[2]		6.74	6.49	6.49	-	-

[1]Interaction effect of S and Mg was significnt; [2]Effect of K was not significant; Means followed by a common letter in a column are not significantly different at 5% level by DMRT.

Table 5

Effect of Mg on total K uptake by rice in two soils under variable applied K levels

Soil(s)	Mg rate (kg ha^{-1})	K rate (kg ha^{-1})			S*Mg-mean[1]	Soil-mean
		0	20	40		
		Total K uptake (kg ha^{-1})				
Guar	0	80.37	95.37	72.91	82.88b	-
	10	109.35	117.03	124.83	117.07a	-
	20	107.61	124.26	127.27	119.71a	106.55a
Hutan	0	25.47	26.39	33.68	28.51d	-
	10	39.43	43.97	47.16	42.52c	-
	20	32.48	35.27	48.44	38.73cd	36.59b
K-mean[2]		65.79	73.72	75.72	-	-

[1]Interaction effect of S and Mg was significnt; [2]Effect of K was not significant; Means followed by a common letter in a column are not significantly different at 5% level by DMRT.

increase was quadratic in nature in Hutan series (Table 6). Higher total Mg uptake in Guar series over Hutan series was attributed to the differences between the soils in grain and straw yields (Tables 2-3). The increase in total Mg uptake due to Mg fertilization was attributed to the increase in grain and straw yields due to Mg fertilization. Previous investigations also showed that Mg application increased Mg uptake by rice significantly (Sahrwat *et al* 1999; Fageria and Souza 1991).

Plant K uptake. Effects of soil and Mg on total K uptake (kg ha^{-1}) were significant (Table 5), whereas K effect was not significant. Interaction effect of soil and Mg was significant. Total K uptake was significantly higher in Guar series over Hutan series. In Guar series, Mg application at 10 or 20 kg

Table 6
Regression equations and R^2 values relating Mg rate with grain and straw yields, Mg and K uptakes in two soils

Soil	Parameter	Regression equation	R^2 value
Guar	Grain yield	$y=4.6717+0.1145x$	0.7989**
	Straw yield	$y=5.1817+0.1275x$	0.7969**
	Total Mg uptake	$y=6.6333+0.337x$	0.9252**
	Total K uptake	$y=88.138+1.8415x$	0.8035**
Hutan	Grain yield	$y=1.58+0.156x-0.0061x^2$	0.993**
	Straw yield	$y=1.75+0.172x-0.0067x^2$	0.978**
	Total Mg uptake	$y=2.01+0.2455x-0.008x^2$	0.991**
	Total K uptake	$y=28.51+2.291x-0.089x^2$	0.995**

**=Significant at 1% level of probability

Mg ha^{-1} increased total K uptake significantly over Mg_0 while in Hutan series Mg effect was significant only at Mg_{10}. Regression analysis indicated that total K uptake increases linearly due to Mg fertilization in Guar series whereas its increase was quadratic in nature in Hutan series (Table 6). Higher total K uptake in Guar series over Hutan series was attributed to the difference between the soils in grain and straw yields (Tables 2 & 3). The increase in K uptake due to Mg fertilization was attributed to the increase in grain and straw yields due to Mg fertilization. On average, total K uptakes were 106.55 and 36.59 kg ha^{-1} in Guar and Hutan series, respectively. These large amounts of K removal indicate that the soils will be depleted in K if K fertilization is not practised. Farmers are applying K in rice cultivation in Malaysia. This practice shloud be continued to maintain soil K status.

Conclusion

The findings of the study indicate that rice yield can be increased through Mg fertilization in Mg deficient soils. Since rice crop removes large amount of K for grain and straw production, the K fertilization practice by the farmers should be continued to maintain soil K status.

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