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Effect of Nitrogen, Copper and Magnesium Fertilization on Yield and Nutrition of Rice

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From a field experiment in Cu and Mg deficient soil conducted in Muda Irrigation Scheme, Kedah, Malaysia, rice yield was found to increase significantly with the additional application of 40 kg N ha^{-1} over farmers' practice (80 kg N ha^{-1}). Application of Cu and Mg in the land either singly or in combination increased rice yields and agronomic efficiency significantly. Highest yields for both the parameters were obtained when Cu and Mg were applied in combination. To get increased rice yield farmers could therefore, be suggested to apply Cu and Mg in combination and higher dose of N over the present rate in the fields, deficient in these two elements.

Key words: Nitrogen, Copper, Magnesium, Rice.

Introduction

The largest rice growing area of Malaysia is located in Muda Irrigation Scheme, Kedah, about 500 km north of Kuala Lumpur. This irrigation scheme covers an area of about 95,000 ha. Farmers are applying a single fertilizer doze of $N_{80}P_{30}K_{20}$ (80 kg N ha^{-1}, 30 kg P_2O_5 ha^{-1} and 20 kg K_2O ha^{-1}) in rice fields throughout the irrigation scheme (Samy *et al* 1992 b). Indiscriminate application of fertilizers throughout the irrigaion scheme caused low yield (3-4 ha^{-1}) in many locations due to Cu and Mg deficiency. Previous study (Choudhury and Khanif 1998) showed that soils were deficient in Cu and Mg in many locations of this irrigation scheme. Similar study (Choundhury and Khanif 2000) also showed that Cu and Mg adsorption capacities of the soils of this area were high. Studies conducted by Malaysian Agricultural Research and Development Institute (MARDI) indicated that the present fertilization practice does not provide adequate N for the rice crop in many areas (Samy *et al* 1992 b). Application of Cu and Mg along with higher N rate (over 80 kg N ha^{-1}) may enhance crop yield. With this view in mind, the present study was undertaken to evaluate the effects of N, Cu and Mg fertilization on yield and nutrition of rice.

Materials and Methods

The experimental site was in Muda Irrigation Scheme, Kedah, Malaysia. The soil series was Tualang possessing the characteristics of very fine clayey, mixed, isohyperthemic and pallid, and belong to Typic Tropaquept (Paramananthan 1998). Before setting the experiment, soil samples were collected from 0-15 cm depth, air dried, ground and sieved through 2-mm sieve. Soils were analyzed for organic matter, pH, cation exchange capacity (CEC), total N, available P, exchangeable K, Mg and Ca, available Zn and Cu according to standard methods (Walkley and Black 1934; Bray and Kurtz 1945; Schollenaberger and Simon 1945; Ponnamperuma *et al* 1981; Bremner and Mulvaney 1982). The results of the determined soil properties are given in Table 1.

The experiment consisted of five treatments. Description of the treatments is presented in Table 2. The field layout and construction of plot boundaries were carried out after land preparation. The experiment was laid out in randomized complete block design (RCBD) with four replications. Unit plot size was 5m x 5m. Total number of plots were 20. Each plot was surrounded by 25 cm boundaries. Each block

Table 1

The soil properties of experimental plots

Properties analysed	Results
Organic matter (%)	4.65
pH	4.2
Cation exchange capacity (cmol kg^{-1})	15.65
Total N (%)	0.12
Available P (mg kg^{-1})	8.2
Exchangeable K (cmol kg^{-1})	0.30
Exchangeable Mg (cmol kg^{-1})	0.25
Exchangeable Ca (cmol kg^{-1})	2.56
Available Zn (mg kg^{-1})	1.60
Available Cu (mg kg^{-1})	0.03

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(replication) was separated from each other by 30 cm drains. Pre-germinated healthy rice seeds of variety MR84 were sown on 10 October 1998. The seed rate for sowing was 70 kg ha^{-1}. Fertilizers were applied in the plots according to the treatments (Table 2). Full dozes of P, K, Mg and Cu were applied as surface broadcasting at 18 days after sowing (DAS). Nitrogen was applied in three splits [1/2 at 18 DAS + 1/4 at active tillering stage (45 DAS) + 1/4 at panicle initiation stage (60 DAS)].

At maturity, plant height, tiller and panicle number m^{-2} were recorded. An area of 3m x 3m was harvested to record grain and straw yields. Harvesting was done on 30 January 1999. After harvesting, threshing was done to separate grain from straw. After drying and cleaning, grain weight and moisture content of grain in each plot were recorded. Grain yield was adjusted at 14% moisture content. Straw weights were recorded for each plot. Straw yield was converted to oven-dry basis. About 10 g of oven-dried representative grain and straw samples were ground to pass through 1mm sieve and kept in plastic containers for chemical analysis. Another 10 panicles, outside the harvest area, were taken randomly from each plot to count filled and unfilled grains, and record 1000 grain weight. Total N content of grain and straw samples was analyzed by H_2SO_4 digestion followed by steam distillation procedure (Yoshida *et al* 1976). Copper content of the plant tissue was analyzed by 1 *N* HCl extraction followed by estimation of Cu by atomic absorption spectrophotometer (Yoshida *et al* 1976). Grain and straw samples were digested with H_2SO_4 and H_2O_2 (Thomas *et al* 1976) and Mg content was measured by atomic absorption spectrophotometer. The uptake of N, Cu and Mg were calculated using yield data (grain and straw) and content of the respective element in grain and straw. The data were analyzed for analysis of variance and means were compared using Duncans Multiple Range Test (DMRT) where F-test was significant (SAS Institute Inc 1987).

Results and Discussion

Yield components and yields. Panicle number m^{-2} increased slightly at higher N rate (120 kg N ha^{-1}) over farmer's practice ($N_{80}P_{30}K_{20}$) although the difference was not significant (Table 3). Application of Cu and Mg both individually or combined along with 120 kg N ha^{-1} increased panicle number m^{-2} significantly over farmer's practice as well as over $N_{120}P_{30}K_{20}$. Treatment effect was not significant on filled grain $panicle^{-1}$. Number of unfilled grain $panicle^{-1}$ decreased significantly at higher N rate (120 kg N ha^{-1}). Addition of Cu or Mg gave less number of unfilled grain $panicle^{-1}$ than $N_{120}P_{30}K_{20}$ although the difference was not significant. Sterility (%) decreased significantly due to application of higher rate of N. Treatment effect was not significant for 100-grain weight.

Treatment effect was not significant on plant height (cm) at maturity, which ranged from 91.50 to 94.75 cm (Table 4). Tiller number m^{-2} increased significantly over farmer's practice due to individual application either Cu or Mg along with higher N doze. Combined application Cu and Mg along with higher N rate gave the highest number of tiller m^{-2}, and it was significantly higher than farmer's practice as $N_{120}P_{30}K_{20}$.

Grain yield (t ha^{-1}) was significantly affected due to application of higher N rate, Cu and Mg (Table 4). An increase of 0.5 t ha^{-1} in grain yield was recorded due to additonal application of 40 kg N ha^{-1} over farmer's practice. Grain yield increased significantly due to addition of either Cu or Mg. Combined application of Cu and Mg gave the highest grain

Table 2

Description of the treatments used in the experiment

Treat-ment No.	Treament	Description
T_1	$N_{80}P_{30}K_{20}$	80 kg N ha^{-1} from Urea + 30 kg P_2O_5 ha^{-1} from Triple super phosphate + 20 kg K_2O ha^{-1} from Muriate of potash
T_2	$N_{120}P_{30}K_{20}Cu_{10}$	T_1 + 40 kg N ha^{-1}
T_3	$N_{120}P_{30}K_{20}Cu_{10}$	T_2 + 10 kg Cu ha^{-1} from copper sulphate
T_4	$N_{120}P_{30}K_{20}Mg_{10}$	T_2 + 10 kg Mg ha^{-1} from magnesium sulphate
T_5	$N_{120}P_{30}K_{20}Cu_{10}Mg_{10}$	T_2 + 10 kg Cu ha^{-1} + 10 kg Mg ha^{-1}

Table 3

Effects of different fertilizer treatments on yield components of rice

Treatment	Panicle number m^{-2}	Filled grain number	Unfilled grain number $panicle^{-1}$	Sterlity (%)	1000 grain weight (g)*
$N_{80}P_{30}K_{20}$	408 b	65	24 a	26.75 a	23.32
$N_{120}P_{30}K_{20}$	420 b	69	18 b	20.75 b	23.36
$N_{120}P_{30}K_{20}Cu_{10}$	480 a	64	17 b	20.25 b	23.99
$N_{120}P_{30}K_{20}Mg_{10}$	469 a	67	17 b	20.50 b	23.34
$N_{120}P_{30}K_{20}Cu_{10}Mg_{10}$	485 a	69	18 b	20.75 b	23.05

*Treatment effect was not significant

Means followed by a common letter in a column are not significantly different at 5% level by DMRT.

yield (7.7 t ha^{-1}), which was significantly higher than all other treatments. Additional yield of 0.7 and 0.6 tha^{-1} over $N_{120}P_{30}K_{20}$ were recorded due to application of Cu and Mg fertilizers, respectively. Combined application of Cu and Mg gave the yield benefits of 1.5 and 1.0 tha^{-1} over farmer's practice and $N_{120}P_{30}K_{20}$, respectively. Agronomic efficiency of N (kg grain kg^{-1} additional N over 80 kg N ha^{-1}) increased significantly due to application of Cu or Mg (Table 4). Agronomic efficiency further increased significantly due to combined application Cu and Mg.

The increase in grain yield (t ha^{-1}) due to additional application of 40 kg N ha^{-1} over farmer's practice indicated that the present N application practice (80 kg N ha^{-1}) was not enough to meet N requirement of rice in this location. Higher yield in 120 kg N ha^{-1} treated plots over 80 kg N ha^{-1} treated plots was attributed to higher number of panicles m^{-2} and filled grain $panicle^{-1}$ as well as lower sterility (%) at N_{120} (Table 3). An increase of 0.5 t ha^{-1} in grain yield was observed at N_{120} over N_{80}. Increases in grain yield of rice due to N fertilization over 80 kg N ha^{-1} were observed in Malysian conditions by other investigators (Arulandoo *et al* 1987; Samy and Arulandoo 1987). Grain yield increase due to application of N fertilizer was also reported by other investigators (Shah *et al* 1996; Zaman *et al* 1996). Farmers are applying 80 kg N ha^{-1} throughout Muda Irrigation Scheme (Samy *et al* 1992 b). The present study therefore indicated that increase in grain yield was related with additional application of 40 kg N ha^{-1} over farmer's practice in this location.

The increase in grain yield due to Cu and Mg fertilization was expected, as the soil was deficient in both Cu and Mg (Table 1). Copper and Mg contents in this soil were below the critical deficiency levels of 0.10 mg kg^{-1} and 0.40 cmol kg^{-1}, respectively (Ponnamperuma *et al* 1981; Sattar and Rahman 1987). Pervious investigations (Ambak and Tadano 1991; Samy *et al* 1992 a) also showed that Cu application increased rice yield in Malaysia. Significant increase in rice yield due to Cu application in soil was reported also from abroad by other investigators (Mehrotra and Saxena 1967; Lopes 1980). The increase in grain yield due to Mg fertilization is in agreement with previous findings (Goswami and Banerjee 1978; Qiming 1991). Agronomic efficiency of N increased significantly due to Cu and Mg fertilization. It indicates that rice crop can utilize N more efficiently for grain production in presence of Cu and Mg in soils, deficient in Cu and Mg. Previous experimental results showed thast Mg application increased fertilizer N recovery (Fenn *et al* 1981; Khanif and Pancras 1992). Farmers are not applying Cu or Mg at all in Muda Irrigation Scheme. This study indicated that there is a prospect to increase grain yield by Cu and Mg fertilization in soils, deficient in Cu and Mg. Highest grain yield and agronomic efficiency of N were obtained by combined application of Cu and Mg. This finding indicated that Cu and Mg should be applied together in rice crop where soil is deficient in both Cu and Mg. Straw yield (tha^{-1}) increased significantly due to application of higher rate of N over farmer's practice (Table 4). Effects of Cu and Mg were significant on straw yield. Straw yield increased significantly over farmer's practice as well as over $N_{120}P_{30}K_{20}$ due to application of either Cu or Mg. The increase in straw yield due to Cu and Mg fertilization was attributed to the increase in tiller number m^{-2} due to Cu and Mg fertilization. Previous investigations showed that Cu fertilization increased tillering of rice plant (Ambak and Tadano 1991; Samy *et al* 1992 b). The increase in straw yield due to Mg fertilization is in agreement with previous findings (Sahrawat *et al* 1999).

Nutrition and uptake nitrogen concentration (%) in grain and straw increased significantly due to application of higher N rate over farmer's practice (Table 5). Application of Cu

Table 4

Effects of different fertilizer treatments on plant height, tiller number, straw and grain yield of rice and agronomic efficiency of added N

Treatment	Plant height (cm)	Tiller number m^{-2}	Straw yield (t ha^{-1})	Grain yield	Agronomic efficiency of N**
$N_{80}P_{30}K_{20}$	94.00	488 c	5.7 c	6.2 d	-
$N_{120}P_{30}K_{20}$	91.50	512 bc	6.5 b	6.7 c	12.5 c
$N_{120}P_{30}K_{20}Cu_{10}$	94.75	520 ab	7.2 a	7.4 b	30.0 b
$N_{120}P_{30}K_{20}Mg_{10}$	94.50	528 ab	7.4 a	7.3 b	27.5 b
$N_{120}P_{30}K_{20}Cu_{10}Mg_{10}$	93.50	544 a	7.6 a	7.7 a	37.5 a

*Treatment effect was not significant
** kg grain per kg additional added N over 80 kg N ha^{-1}
Means followed by a common letter in a column are not significantly different at 5% level by DMRT.

Table 5

Effects of different fertilizer treatments on N uptake by rice

Treatment	N content (%)		N uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
$N_{80}P_{30}K_{20}$	1.21 b	0.46 b	74.97 c	26.00 c	100.97c
$N_{120}P_{30}K_{20}$	1.32 a	0.57 a	88.85 b	36.78 b	125.63 b
$N_{120}P_{30}K_{20}Cu_{10}$	1.37 a	0.67 a	100.61 a	48.33 a	148.94 a
$N_{120}P_{30}K_{20}Mg_{10}$	1.39 a	0.65 a	101.04 a	48.47 a	149.51 a
$N_{120}P_{30}K_{20}Cu_{10}Mg_{10}$	1.40 a	0.64 a	106.74 a	48.52 a	155.26 a

Means followed by a common letter in a column are not significantly different at 5% level by DMRT.

and Mg increased N content in grain and straw slightly over $N_{120}P_{30}K_{20}$ although the difference were not statistically significant. Nitrogen uptake (grain, straw and total) increased significantly due to application of higher N rate over farmer's practice. Application of Cu and Mg either individually or combined increased N uptake (kg ha^{-1}) significantly over $N_{120}P_{30}K_{20}$. The highest total N uptake (155.26 kg ha^{-1}) was recorded in $N_{120}P_{30}K_{20}Cu_{10}Mg_{10}$ treated plot while the lowest N uptake (100.97 kg ha^{-1}) was recorded in farmer's practice. The increase in total N uptake (kg ha^{-1}) due to additional application of 40 kg N ha^{-1} over farmer's practice was attributed to the increase in yield (grain and straw) and N concentration (grain and straw). The increase in total N uptake due to Cu and Mg application was attributed to the increase in grain and straw yields. Previous investigations (Samy and Arulandoo 1987; Choudhury and Bhuiyan 1994) showed that total N uptake increased significantly with increasing N rates.

Copper content (mg kg^{-1}) in grain and straw increased significantly due to Cu fertilization (Table 6). Copper content in straw was below the critical deficiency level of 6 mg kg^{-1} (Yoshida *et al* 1976) without Cu application while it was above the critical deficiency level when Cu was applied. It was expected as the soil was deficient in Cu (Table 1). Copper content in the soil was below the critical deficiency level of 0.10 mg kg^{-1} (Ponnamperuma *et al* 1981). Copper uptake (grain, straw and total) increased significantly due to Cu fertilization. Magnesium fertilization also increased Cu uptake significantly over farmer's practice. Total Cu uptake ranged from 105.09 to 108.01 g ha^{-1} in Cu treated plots while the range was 58.81 to 79.74 g ha^{-1} in untreated plots. The increase in Cu concentration in grain and straw due to Cu fertilization is in agreement with previous findings (Ambak and Tadano 1991). Magnesium concentration in grain and straw were significantly higher in Mg treated plots compared to untreated plots (Table 7). Magnesium concentration in straw was below the critical level of 0.10% without Mg application while it was above the critical deficiency level when Mg was applied. This was expected as the soil was deficient in Mg (Table 1). Magnesium content in this soil was below the critical deficiency level of 0.40 cmol kg^{-1} (Sattar and Rahman 1987). Magnesium contents in grain and straw were significantly lower in the plots those received both Cu and Mg compared to only Mg treated plots. This was due to dilution effect attributed to higher grain and straw yields in the plots those received both Cu and Mg. Magnesium uptake (grain, straw and total) increased significantly due to Mg fertilization. This was attributed to the increase in yield (grain and straw) and Mg concentration (grain and straw) due to Mg fertilization. This was attributed to the increase in yield (grain and straw) and Mg concentration (grain ans straw) due to Mg fertilization. Previous investigations also showed that Mg uptake increased significantly due to Mg fertilization (Fageria and Souza 1991; Sahrawat *et al* 1999).

Table 6

Effects of different fertilizer treatments on Cu nutrition of and Cu uptake by rice

Treatment	Cu content (mg kg^{-1})		Cu uptake (g ha^{-1})		
	Grain	Straw	Grain	Straw	Total
$N_{80}P_{30}K_{20}$	4.90 b	5.00 b	30.30 c	28.51 c	58.81c
$N_{120}P_{30}K_{20}$	5.34 b	5.45 b	35.93 bc	35.34 bc	71.27 bc
$N_{120}P_{30}K_{20}Cu_{10}$	7.31 a	7.46 a	53.92 a	54.09 a	108.01 a
$N_{120}P_{30}K_{20}Mg_{10}$	5.37 b	5.48 b	38.99 b	40.75 b	79.74 b
$N_{120}P_{30}K_{20}Cu_{10}Mg_{10}$	6.81 a	6.95 a	52.24 a	52.85 a	105.09 a

Means followed by a common letter in a column are not significantly different at 5% level by DM.

Table 7

Effects of different fertilizer treatments on Mg uptake by rice

Treatment	Mg content (%)		Mg uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
$N_{80}P_{30}K_{20}$	0.07 c	0.09 c	4.02 b	4.48 b	8.86 b
$N_{120}P_{30}K_{20}$	0.06 c	0.08 c	3.70 b	4.87 b	8.57 b
$N_{120}P_{30}K_{20}Cu_{10}$	0.06 c	0.08 c	4.05 b	5.43 b	9.48 b
$N_{120}P_{30}K_{20}Mg_{10}$	0.11 a	0.13 a	7.63 a	9.29 a	16.91 a
$N_{120}P_{30}K_{20}Cu_{10}Mg_{10}$	0.10 b	0.12 b	7.28 a	8.70 a	15.98 a

Means followed by a common letter in a column are not significant at 5% level by DMRT.

Conclusion

The findings of the study indicate that there is a prospect to increase rice yield and agronomic efficiency of N with the combined application of Cu and Mg in soils, deficient in both these elements. Higher N doze over the present farmers practice in Muda Irrigation Scheme is needed to increase rice yield.

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