ISSN: 1394-7990
Malaysian Journal of Soil Science Vol. 14: 71-82 (2010) Malaysian Society of Soil Science

Effects of Micronutrient Fertilizers on the Production of MR 219 Rice (*Oryza sativa* L.)

Y.A. Liew [1*], S. R. Syed Omar [1], M.H.A Husni [1], M.A. Zainal Abidin[2] & N.A.P. Abdullah[3]

[1]Department of Land Management, [2]Department of Plant Protection, [3]Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

ABSTRACT

Poor management of plant nutrients and ignorance of the Liebig's Law of Minimum for plant nutrients requirement is an obstacle in efforts to increase rice production in Malaysia. Ignorance of the importance of micronutrients application by Malaysian farmers hinders the achievement of high yields in rice production. Six farmers' plots were used to examine the importance of micronutrients in rice production in Sawah Sempadan, Tanjong Karang, Malaysia. Soil and foliar samples were collected and analyzed to determine the micronutrients content and then compared with the critical nutrients levels needed by rice. Special fertilizers comprising formulated mixture of K, Mg, Zn, Cu, Mn and B were then distributed to farmers along with a recommended manuring programme. The timing and quantity of fertilizer applied were closely supervised. The investigations were carried out over two continuous seasons where rice yield data were collected and subjected to statistical analysis. The results showed that the application of special fertilizers in conjunction with proper field maintenance was able to increase rice production by 27%, from 4.62 tonnes per hectare to 5.87 tonnes per hectare.

Keywords: Fertilizer, Law of Minimum, micronutrients, rice

INTRODUCTION

Rice is a staple food for more than 3 billion people in the world (IRRI 2005). Malaysians also consume rice as their staple food. However, rice self-sufficiency level for Malaysia was 72% in 2007. In line with the National Agriculture Policy, the government wishes to increase the rice self-sufficiency level up to 86% by 2010.

The increase in rice production can be achieved by efficient and good agricultural practices, water and nutrients inputs. However, poor management of plant nutrients and ignorance of the Liebig's Law of Minimum serves as a hurdle in efforts to increase rice production in Malaysia. While Malaysian farmers apply N, P and K fertilizers widely, it is found that the applications of micronutrients such as Zn, Cu, Mn and B is not a usual practice. A marked higher incidence of micronutrient deficiencies is found in crop due to intensive cropping, loss of fertile topsoil and losses of nutrients through leaching (Somani 2008). Soils

*Corresponding author : E-mail: *butterliew@yahoo.com*

deficient in their supply of crop micronutrients are alarmingly widespread across the globe. Low levels of trace elements are expected in the oldest landscapes in zones of high rainfall and temperature, and where trace element concentrations in parent materials are originally low (White and Zasoski 1999). The presence of micronutrient deficiency, renders it impossible for the plant to gain maximum benefit from NPK fertilizer applications. Micronutrients have been categorized as essential even though needed in minute amounts. Plants cannot complete their life cycle in the absence of micronutrients (Marschner 1995).

In Malaysia, most of the granary areas are well established with irrigation systems with the farmers practising double cropping with high yielding varieties such as MR 219 or MR 220 (Ho *et al.* 2008). The intensive cropping on the same piece of land with high yielding varieties requires better fertilizer management as it is known that long-term cropping will alter the availability of soil micronutrients (Wei *et al*. 2006). Thus, the sole application of solely NPK fertilizers is no longer practical due to the continuous removal of micronutrients after harvesting, as well as losses due to leaching or surface runoffs. The objective of this study is to investigate the effects of micronutrient applications on MR219 rice yields under field conditions.

MATERIALS AND METHODS

Field experiments were conducted at Sawah Sempadan, Kampung Seri Tiram Jaya, Tanjong Karang (3° 28' 0" North, 101° 13' 0" East), Selangor over two planting seasons: one was off-season (July 2007 – November 2007) and the other a main season (January 2008 – May 2008). Rice cultivars used in the experiments were MR219 supplied by the Malaysian Agricultural Research and Development Institute (MARDI). The experiments were conducted on six different farmers' plots located at Block E and Block F in Sawah Sempadan area. The soil series was Sedu, an acid sulfate soi classified as fine, mixed, isohyperthermic Typic Sulfaquent by USDA Soil Taxonomy System. This area had been cultivated with paddy for more than 25 years by farmers using chemical fertilizers and pesticides widely. However, no additional micronutrient fertilises were applied other than the subsidized fertilizer given by the Malaysian government. This area has been experiencing low rice yields with the average production being 4.5 tonnes per hectare, with severe infections of fungal diseases namely Brown Spot (*Drechslera oryzae*) and Sheath Blight (*Rhizoctonia solani*).

Soil samples were randomly collected from 3 different spots in each of the experimental plot. Flag leaves of the rice plant at maximum tillering were randomly sampled from the experiment plot. Soil and leaves samples collected were analyzed for nutrient content according to the methods listed in Table 1. Plant nutrient contents in the soil and leaves samples (Tables 2 and 3) were compared with the critical nutrients range required by rice as reported by Dobermann and Fairhurst (2000) (Tables 4 and 5). Subsequently, special formulated fertilizers of 125 kg containing mixtures of several macro- and micronutrients namely K, Mg, Zn, Cu, Mn and B were prepared and distributed to the individual farmers (Table 6)

Table 1
Methods of Soil and Plant Analysis

Samples	Chemical Properties	Method of Analysis
Soil	Total Carbon	Dry combustion with total carbon analyzer
	Extractable P	Bray 2 method (0.1N HCl + 0.03N NH_4F)
	Extractable K, Ca, Mg	Shaking with 1 N ammonium acetate, pH 7 (1:5 v/w)
	Extractable Zn, Mn, Cu, Fe	Mehlich No. 1 (0.05 N HCl + 0.025 N H_2SO_4)
	Extractable B	Hot water (1:2 v/w)
	pH	pH water (1:1 v/w)
Leaf	Total Nitrogen	Kjedahl Method
	P, K, Ca, Mg,	Dry ashing
	Zn, Mn, Cu, Fe, B	

Source : Jones (2001)

TABLE 2
Nutrients content in soil samples

Nutrient	Total C	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B	pH
	(%)	mg kg^{-1}									
Concentration in soil samples	12.01	37.23	72.36	293.36	119.64	1.11	5.27	0.12	91.5	0.15	4.61
Standard error	0.92	3.67	3.99	28.97	8.72	0.07	0.16	0.0104	3.81	0.07	0.03

TABLE 3
Nutrients content in leaf samples

Nutrient	N	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B
	(%)					mg kg^{-1}				
Concentration in leaf samples	2.38	0.18	1.01	1.88	0.38	39.45	247.53	8.29	324.45	0.32
Standard error	0.069	0.006	0.045	0.027	0.008	3.45	38.27	1.31	51.05	0.25

TABLE 4
Critical nutrient concentration in soil planted with rice

Nutrients	P	K	Ca	Mg	Zn	Mn	Cu)	Fe	B
					mg kg^{-1}				
Critical nutrients concentration in soil	12 -20	15	20	36	1	3 – 30	0.1	4 - 5	0.5

Source : Dobermann and Fairhurst (2000)

TABLE 5
Critical nutrient concentration in leaf for rice

Nutrients	N	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B
			(%)					mg kg^{-1}		
Critical nutrients concentration in leaves	> 2.0	> 0.18	>1.5	> 0.15	> 0.15	25 – 50	40 - 700	7 - 15	75 - 150	6 – 15

Source : Dobermann and Fairhurst (2000)

TABLE 6
'Spedial Formulated Fertilizers" for 1 ha of rice field

Fertiliser	$CuSO_4$	$ZnSO_4$	$MnSO_4$	Boron Etibor 48	Cal. Borate	Kieserite	MOP
Weight of fertiliser	10 kg	10 kg	5 kg	15 kg (48% B_2O_3)	10 kg (9% B_2O_3)	15 kg	60 kg
Equivalent weight of nutrient	4 kg of Cu	4 kg of Zn	3.6 kg of Mn	2 kg of B	0.25 kg of B	2.43 kg Mg	29.9 kg K

These fertilizers were supplied along with a special manuring programme (Table 7) where time and quantity of fertilizer applications were predetermined. Farmers involved in the experiments were required to follow precisely the given practices in their fertilizer management programme. Field maintenance and use of pesticides were based on normal practices. Data were collected during harvesting for two subsequent seasons.The total yields harvested by a combined harvester at the experimental plots were recorded at the weighing bridge. Data collected were subjected to analyses of variance (ANOVA) performed using the SAS program to determine statistical significance of the effect of treatments. If F-values were found to significant, LSD test was performed for means comparison.

TABLE 7
Manuring programme schedule for participating farmers

Time of fertilizer application	Fertilizer application for one farmer's lot (1.2 hectares)
15 DAS	120 kg of subsidized NPK fertilizer (17.5 : 15.5 : 10)
25 DAS	Foliar spray of 480 mL Robust® + 900 mL Vita-Grow Plus®
30 DAS	125 kg 'Special Formulated Fertilizer ' + 120 kg of subsidized Urea (46% N)
45 DAS	Foliar spray of 900 mL of Robust® + 900 mL of Vita-Grow Plus®
55 DAS	180 kg of subsidized NPK Fertilizer (17.5 : 15.5 : 10)
65 DAS	Foliar Spray of 900 mL of Robust® + 900 mL of Vita-Grow Plus
85 DAS	Foliar spray of 1,200 mL of Robust®

* DAS = Days after seeding

RESULTS AND DISCUSSION

Nutrients contents in the soil and leaves samples analyzed were compared with the critical nutrients range required by rice as reported by Dobermann and Fairhurst (2000). The results showed that the soil was low in Zn, Cu and B contents. The foliar analysis showed that the K, Cu and B contents in leaf samples were far from optimum for rice production.

Rice production in the six experimental plots showed significant improvement. The special fertilizers served to increase the rice yield from 4.62 tonnes per hectare at the main season 2007 (untreated season, prior to this study) to 5.87 tonnes per hectare at off-season 2007 (Table 8) which accounted for a 27% increment with only one treatment. However, the increment in the second season of the experiment showed no significant difference and this was mainly due to a disease

outbreak. A comparison between the yields harvested by the six farmers, showed that farmer D had significantly lower yields than farmer E (Table 9).

TABLE 8
Effects of special formulated on rice yield for two experimental seasons

Experimental season	Rice yield (tonnes per hectare)
Untreated Season (main season 2007)	4.62 b
Experiment Season 1 (off -season 2007)	5.87 a
Experiment Season 2 (main season 2008)	4.97 b

* Means followed with the same letter are not significantly different at 5% level by LSD

TABLE 9
Comparison of rice yields harvested by six farmers

Farmers	Rice yield (tonnes per hectare)
E	6.65a
B	5.84ab
F	5.83ab
A	5.16ab
C	4.84 ab
D	4.21b

* Means followed with the same letter are not significantly different at 5% level by LSD

Micronutrients deficiencies develop over time in intensive farming systems and are likely due to large amounts of nitrogen, phosphorous, potassium fertilizers and lime applications that promote nutrient imbalances, increasing micronutrients demand, altering micronutrients availability, and hastening the depletion of readily available soil micronutrients pool (White and Zasoski 1999). Intensive

rice farming of two seasons a year further depletes the exhausted micronutrients pool in the soil.

The significant yield increment seen in the off-season of 2007, compared with the untreated season (main season 2007), was due to the combination effect of the special fertilizer. The special fertilizer provided was formulated according to the requirements of the selected experimental site. The nutrients added were namely 29.9 kg of K, 4 kg of Cu, 4 kg of Zn, 3.6 kg of Mn, 2.43 kg of Mg and 2.25 kg of B per hectare (Table 5) for 1 farmer in order to replenish nutrients low in the soil as well as promote the availability of these elements for plant uptake. According to Dobermann et al. (1998), K deficiency is a constraint to increasing yields, even on heavy-textured lowland soils with high inherent fertility. Thus, addition of a special fertilizer with 29.9 kg of K was found to markedly increase the rice production during the first season of the experiment. Potassium has been identified by Dobermann and Fairhurst (2000) to play a crucial role in enhancing the number of spikelets per panicle, percentage of filled grains and 1,000 grain weight in rice. Moreover, they also reported that the lack of K and an imbalance in nutrients management may cause severe disease infestation. It has also been reported that K removal in rice produced in rain-fed lowland light-textured soils exceeded K additions via fertilizer application and the soil K balance was negative unless crop residue such as farm yard manure was incorporated (Wihardjaka et al. 1999). Potassium depreciation and the removal of soil K reserves in intensive rice cultivated area is well known. Dobermann *et al.* (1996) suggests that the K uptake requirement of rice ranges from 17 to 30 kg K per tonne of grains, accounting for a total of 200 kg K per ha for yield production greater than 8 tonnes per ha. The experimental site was heavily infested by diseases particularly brown spot (Drechslera oryzae) and sheath blight (Rhizoctonia solani). Results from the soil and foliar analysis indicated that the plants in the experimental area were experiencing low inherent soil micronutrients from the soil especially Zn, Cu and B. Application of the special fertilizer to the depleted paddy soils that have been cultivated for more than 25 years boosted the rice production due to the combination effect of the applied nutrients. Work done by Heitholt et al. (2002) and Buri et al. (2000) suggest that micronutrients could be the limiting factors in crop production. Somani (2008) and Marschner (1995) suggest that addition of micronutrients in the crop production system could reduce nutrients imbalance, producing healthier plants and increased crop yields.

Zinc has been identified as one of the most limiting factors in rice production (Yang *et al*. 2009). The low Zn concentration and availability in topsoil need to be corrected by fertilizer addition and/or recycling of organic matter to provide a balanced nutrient environment that favours rice production (Buri *et al.* 2000). Zinc has been long associated with the tillering of the rice plant. Under severe Zn deficiency, tillering of the rice plant will be greatly affected and may stop completely (Dobermann and Fairhurst 2000). Zinc deficiency is also known too dramatically increase spikelet sterility in rice (Dobermann and Fairhurst 2000) and this had been confirmed by research done by Yang *et al.* (2009). They found

Zn deficiency in soil to cause a remarkable reduction in the seed yield, causing a serious decline in rapeseed yield. Kalayci *et al*. (1999) reported that Zn fertilization of wheat in the field can greatly enhance grain production at an average of 30%.

Copper plays an important role in activating the enzymatic activities and is required for lignin synthesis. Dobermann and Fairhurst (2000) indicate that Cu plays a key role in nitrogen, protein and hormone metabolism, photosynthesis and respiration, and pollen formation and fertilization in rice. Marschner (1995) reported Cu deficiency affects grain, seed and fruit formation especially in soil with high organic matter where Cu is complexed to the organic substances. The experimental plots consisted of a high total carbon content of more than 12% (Table 1) and this may contribute to the formation of organic-Cu complexes which are not available for plant uptake. Impairment of lignin formation due to Cu deficiency may favour the incidence of disease outbreak. Lignin is the primary defense mechanism in plants with the cross-linked phenolic polymer serving as the natural barrier for penetration of fungal pathogens; it is known to strengthen and protect the cell wall from degradation (Bird 1988; Rice 2007; Evans *et al.* 2007).

Boron deficiency causes great depreciation in grain set and results in severe yield reduction in many of the world's grain producing countries (Rerkasem et al. 2004). Marschner (1995) states that B is required by plants for carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis and respiration. Boron deficiency causes reduced plant height and severe deficiency, resulting in the death of the growing points. Rice plant is sensitive to B deficiency especially at the panicle formation stage and insufficient boron application may lead to failure in panicle formation (Dobermann and Fairhurst 2000). Boron also plays a key role in pollen germination and pollen tube growth where it is responsible for seed and grain production (Marschner 1995). Rerkasem and Jamjod (2004) found that B deficiency depressed commercial wheat yield due to grain set failure, caused by male sterility when the wheat anthers were impaired by limited B concentration in tissue.

The addition of a special fertilizer consisting of six nutrients inclusive of four micronutrients (Zn, Cu, B and Mn) significantly boosted the rice yield in the experimental site during the off-season (2007) due to the combination effect of the added nutrients especially in relation to micronutrients that had been depleted in the soil. The conventional approach of nutrients management in rice planting which emphasizes N, P and K application has resulted in nutrients imbalance in the soil. Micronutrients are exhausted over a long period of intensive bi-season rice farming of high-yielding cultivars; such cultivars require extensive amounts of nutrients to support their production. Nutrients mining due to an imbalance in nutrient management and ignorance of Liebig's Law of Minimum reduce rice production. An imbalance in nutrients management, especially N, favours insect pest attack and contributes to high disease outbreaks in rice farming areas. More research should be carried out to study plant nutrients and disease interaction in order to increase rice production in Malaysia.

CONCLUSION

This study showed that applications of a special fertilizer formulated from 29.9 kg K, 4 kg of Cu, 4 kg of Zn, 3.6 kg of Mn, 2.43 kg of Mg and 2.25 kg of B could increase rice yield by 27%, from 4.62 tonnes to 5.87 tonnes per hectare. The increased rice production is due to the combined effect of the applied nutrients which appear to alter the nutrients imbalance in a rice planting area which has undergone a long, continuous period of bi-season intensive rice farming.

ACKNOWLEDGEMENTS

The authors gratefully acknowledged Diversatech Fertilizer (M) Sdn. Bhd. for providing the micronutrients fertilizer to be used in this study, and also the staff of Pertubuhan Peladang Kawasan (PPK) Tanjong Karang, Selangor, for their assistance in the field sampling.

REFERENCES

Bird, P. M. 1988. The Role of Ligninfication in Plant Diseases. In Experimental and Conceptual Plant Pathology Volume 3: Defence. Singh *et al*. (eds). Gordon and Breach Science Publishers.

Buri, M. M., T. Masunaga and T.Wakatsuki 2000. Sulfur and zinc levels as limiting factors to rice production in West Africa lowlands. *Geoderma* **94**: 23-42.

Dobermann, A., K.G. Cassman, C.P. Mamaril and J.E. Sheehy. 1998. Management of phosphorous, potassium, and sulfur in intensive, irrigated lowland rice. *Field Crops Research* **56:**113 – 138.

Dobermann, A., Cruz, P. C. Sta. and K.G. Cassman. 1996. Fertilizer inputs, nutrient balance, and soil nutrient-supplying power in intensive, irrigated rice system. I. Potassium uptake and K balance. *Nutrient Cycling in Agroecosystem* **46**: 1-10

Dobermann, A. and T. Fairhurst. 2000. Rice – Nutrient Disorder and Nutrient Management. 1st Edition. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute (IRRI). 2000. pp. 40 – 117.

Evans, I., E. Solberg and D.M. Huber. 2007. Copper and Plant Diseases. In Mineral Nutrition and Plant Disease. Datnoff *et al*. (eds.). The American Phytopathological Society.

Heitholt, J. J., J.J. Sloan and C.T. MacKown. 2002. Copper, manganese and zinc fertilization effects on growth of soybean on a calcareous soil. *Journal of Plant Nutrition* **25 (8)**: 1727-1740.

Ho, N. K., S. Jegatheesan and F.K. Phang. 2008. Increasing Rice Productivity in Malaysia – an Independent View. National Conference & Workshop on Food Security, 2-3 December 2008. Hotel Istana, Kuala Lumpur.

International Rice Research Institute (IRRI). 2005. Rice. International Rice Reasearch Institute. Las Banas, Phillipines.

Jones, B. J. J. 2001. pp. 41-211. Laboratory Guide for Conducting Soil Tests and Plant Analysis. CRC Press. 2001.

Kalayei, M., B. Torun, S. Eker, M. Aydin, L. Qzturk and I. Cakmak . 1999. Grain yield, zinc efficiency and zinc concentration of wheat cultivars grown in a zinc-deficient calcareous soil in field and greenhouse. *Field Crops Research* **63**: 87-98.

Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd Edition. Academic Press, London.

Rerkasem, B. and S. Jamjod. 2004. Boron deficiency in wheat: a review. *Field Crops Research* **89:** 73-186.

Rerkasem, B., S. Nirantrayagul and S. Jamjod. 2004. Increasing boron efficiency in international bread wheat, durum wheat, triticale and barley germplasm will boost production on soil low in boron. *Field Crops Research* **86:**175-184.

Rice, R. W. 2007. The Physiological Role of Minerals in the Plant. In Mineral Nutrition and Plant Disease. Datnoff *et al.* (eds.). The American Phytopathological Society.

Somani, L. L. 2008. pp. 14-74. Micronutrients for Soil and Plant Health. Agrotech Publishing Academy.

Wei, X. R., M.D. Hao, M. Shao and W.J. Gale. 2006. Changes in soil properties and the availability of soil micronutrients after 18 years of cropping and fertilization. *Soil and Tillage Research* **91**: 120 – 130.

White, J. G. and R.J. Zasoski . 1999. Mapping Soil Micronutrients. *Field Crops Research* **60**: 11 – 26.

Wihardjaka, A., G.J. D. Kirk, S. Abdulrachman and C.P. Mamaril. 1999. Potassium balances in rainfed lowland rice on a light-textured soil. *Field Crops Research* **64:**237-247.

Yang, M., L. Shi, F.S. Xu, J. W Lu, and Y.H. Wang. 2009. Effects of B, Mo, Zn, and their interactions on seed yield of rapeseed (*Brassica napus* L.). *Pedosphere* **19 (11)**: 53-59.