The Eurasia Proceedings of Science, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2018

Volume 2, Pages 159-166

ICRES 2018: International Conference on Research in Education and Science

Urea Containing Coated Cu and Zn: A Suitable Fertilizer for Healthier Growth of Rice and N-Uptake

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Abstract: Micronutrient deficiency is predominant globally hence a hurdle to achieve healthy crop growth and ultimately the yield. Malaysian acidic soils are also in same occurrence of micronutrient insufficiency because of subsidized (macronutrients) fertilizer performs. Repetitive fertilizer practices without retrieving nutrient contents in the soil may result on the growth and quality of rice. In this regard a pot experiment was organized on two soils; Kedah and Kelantan the main rice growing areas of Malaysia. The aim was to evaluate the effects of Cu and Zn coated urea on rice growth and N-uptake. Copper (at the rate of 3 & 5 kg ha^{-1}) Zn (at the rate of 7 & 10 kg ha^{-1}) as single and combined together, wrapped with coated and un-coated urea along with the suggested doses of NPK; 140, 70 and 70 kg ha^{-1} respectively were applied. Application of coated urea in combination of Cu and Zn had positive effect on all the growth parameters, chlorophyll contents and N-efficiency in acidic soils. Mean comparison between treatments showed, the significant effect of combined (Cu and Zn) coated urea as compared to individual surface application of Cu and Zn. The growth parameters increment was recorded by 30-40% over control. Furthermore, the N, Cu and Zn contents in the soils along with chlorophyll contents in rice plants were also increased significantly ($p<0.05$) in combined Cu and Zn coated urea applied soils over control. This increase in growth parameters is a confirmation of Cu and Zn coated urea application for better rice yield.

Keywords: Coated urea, Copper, Zinc, Paddy, Acidic soils

Introduction

The world's population with food and fiber demand is increasing at an alarming rate. It supposed to be 35% more population than the current 6.9 billion by the year 2050 (Ennis et al., 2011). Rice is the main staple food of the world's population. More than 50 percent people depend on this basic staple food. Therefore making it affordable for the poor is particularly decisive (Godfray et al., 2010). Among the leading 25 rice producing countries, Malaysia in one of them with an annual production 2.51 million metric tons (Stat). Rice known as a meal for the entire population in Malaysia too, but its production is limited to specifically designated areas. These designated areas called as granary areas of Malaysia which consisting on eight parts (Kamaruddin, et al., 2013). The Malaysia is still far behind the target of self- sufficiency in rice production. There are the numbers of factor affecting on Malaysia's self-sufficiency in rice production; among them the most commonly observed one is imbalance fertilizer practices. The application of NPK fertilizers along with intensive cultivation of high yielding varieties have been ultimately resulted in micronutrients deficiencies in soil and plants (Cakmak, 2002). Worldwide, the reports have proven inadequacy of Zn, Cu and Fe as compared to the rest of the other

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

micronutrients. Rice is sensitive to micronutrients, deficiency of such nutrients in rice can cause drastic decline in production and become major constraints to productivity, durability and unremitting life of soils (Bell and Dell, 2008). Malaysian soils are acidic in nature and are expected to no deficiency for micronutrients. Rice farmers in the certain regions applied the subsidized fertilizer, virtually without micronutrient fertilizer application. However the facts have proven the micronutrients deficiency (zinc and boron) in Malaysia and the affirmative application of these micronutrients in the form of fertilizer have eventually enhance rice production (Hafeezullah, 2010; Saleem et al., 2010).

Micronutrients are involved in the number of indispensable processes in plant. In particular, micronutrients Cu and Zn are required for numerous essential progressions especially in cereals. Rice plant is unable to complete its biochemical processes, such as synthesizing of nucleotide and cytochrome; auxin metabolism and producing chlorophyll; as well as activating enzymes and maintenance of membrane integrity. The copper serves as effector, stabilizer and inhibitor, and also as catalyst of oxidation reaction in the plant. It is particularly important in N, proteins and hormone metabolism. At the same time, it is involved in photosynthesis and respiration a mechanism which ultimately affects pollen formation and fertilization (Dobermann and Fairhurst, 2000). Thus the current study was designed in such a manner, so can cover the important aspects of micronutrient coated fertilizer on the growth and N-uptake of rice plant. The objectives of this research are to compare the response of coated and un-coated urea with Cu and Zn on the growth components of rice and on N-efficiency along with its effect on micronutrients availability.

Method

The experiment was conducted in the glasshouse of Universiti Putra Malaysia on two different soil series. Cempaka (riverine alluvium) Kelantan, located on the latitude of 05-97370N and longitude of 102-29944, and Kuala Kedah (marine alluvium) Kedah located on the latitude of 06-13422N and longitude of 100.29527E on Global Positioning System (GPS). Twenty days old seedlings of rice variety MR-219 were transplanted in the pots. The pots were arranged in Randomizes Complete Block Design (RCBD) with three replications. Copper (Cu) and zinc (Zn) either alone or in the combinations were applied in the form of surface application and coated with urea.

Treatments detail

There were seventeen treatments used; control (without Cu and Zn application), Cu (3 kg ha^{-1} and 5 kg ha^{-1}) in the form of $CuSO_4$, Zn (7 kg ha^{-1} and 10 kg ha^{-1}) in the form of $ZnSO_4$ with and without coating of urea. The recommended doses of NPK in the form of urea, triple super phosphate, muriate of potash at the rate of 140, 70 and 70 kg ha^{-1} has been applied. Each pot filled with the 10 kg of soil. The soil conditions were leveled before sowing. The big soil clods broken with hands in each pot and soil remained saturated for one week.

Observations

Plant growth parameters; plant height (cm), number of tillers $plant^{-1}$, number of panicle $plant^{-1}$, panicle length $plant^{-1}$, panicle weight (g), and nutrients contents were determined (Dobermann and Fairhurst, 2000). These observations were taken from each treatment with three imitates. Average of each parameter was elaborated for the further analysis.

Soil analysis

Soil texture was determined by the pipette method (Gee and Bauder, 1986). Soil pH examined in soil-water solution 1:1 (v/w) using PHM210 Standard pH meter (Jones Jr, 2001). Total N was determined by employing the Kjeldhal method (Bremner and Mulvaney, 1982). Soil available P was extracted by using Bray and Kurtz #2 (Bray and Kurtz, 1945). Ammonium extractable K (Hanway and Heidel, 1952) was assessed by flame photometry. Soil available Cu and Zn contents were obtained by using Mehlich-I (soil to water ratio 1:5, soil 5g and 25 mL of double acids; 0.05 N HCl and 0.025 N H_2SO_4) shaking time 15 minutes at 180 rpm used mechanical shaker, contents were determined on Atomic Absorption Spectrophotometer (Jones Jr, 2001).

Chlorophyll contents

A leaf chlorophyll content (SPAD) value was determined at middle of the growth period of rice plant. In this regard a portable chlorophyll meter (MINOLTATM SPAD-502) was adopted (Peterson, 1993) to record the values. From each treatment the youngest fully expanded leaf (YEL) pot^{-1} was selected for the observation. The amount of the green color in the leaf tissue is illustrated by the SPAD readings which is associated with the actual chlorophyll content of the leaf tissue.

Plant analysis

To evaluate the nutrient contents in rice plants; one plant pot^{-1} was selected at the middle growing stage of rice. Plant samples were properly washed with distilled water and dried on the room temperature, as the moisture contents dries up the samples were placed in the oven at 65^{o}C for 48hours. Plant tissue samples were ground after they completely dries up. Determination of Cu and Zn was done with dry ashing method of plant analysis. In this regard 0.25 g of tissue (placing in furnace for 6 hours to make it in the ash form) was taken and added 2 mL of concentrated hydrochloric acid (HCl) and 10 mL of 20% nitric acid (20 mL HNO_3 + 100 mL of distilled water (D.W)) in to it. Samples were placed in water bath for one and half hour to let them dry. Then samples were diluted with D.W and the final volume made at 50 mL in volumetric flask. The filtered extract was analysed on Atomic Absorption Spectrophotometer. For N analysis, Kjeldhal procedure was followed (Jones Jr, 2001).

Statistical analysis

The data were statistically analyzed by using Statistix version 8.1. Analysis Of Variance (ANOVA) of Randomized Complete Block Design (RCBD) was carried out followed by the mean comparison of Tukey's range test at 5% level of confidence to estimate the treatments effect over control.

Results and Discussion

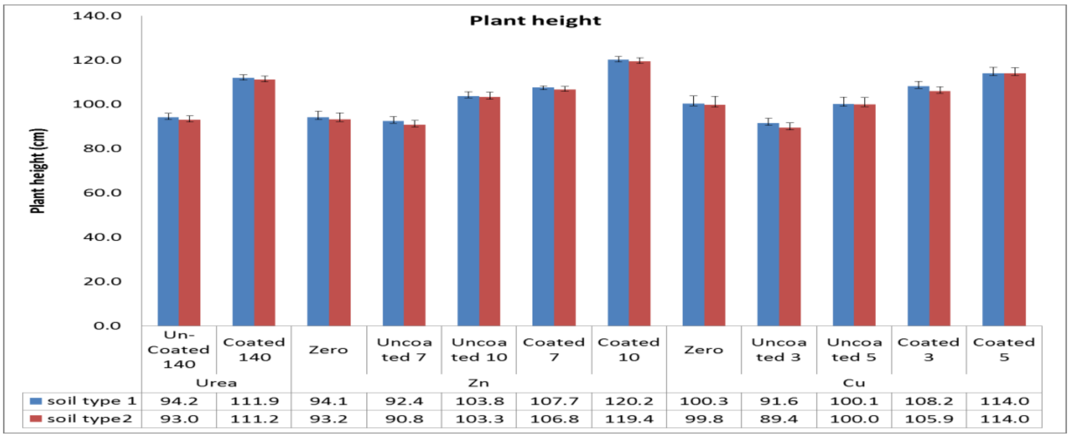
The soils from Kedah are generally derived from marine alluvium and Kelantan plains are derived from riverine alluvium. Both soils have distinct soil characteristics in terms of physical and chemical properties. The soil texture of riverine alluvium belt of Kelantan soil is mostly found loamy, whereas the marine belt from Kedah has more clay contents in their textural class. Micronutrients nonexistence have reported earlier in Kelantan plains (Soo, 1975) and similar conditions were found so in Kedah (Hafeezullah, 2010; Saleem et al., 2010). The results from the current research revealed the Cu and Zn deficiency in respective soils of Kelantan and Kedah (Table 1). Analysis of the other macronutrients found to be normal. The soil-1 represents soil series Chempaka (riverine alluvium) from Kelantan, whereas soil-2 characterizes the soil series Kuala Kedah (marine alluvium) Kedah in Table 1. The application of particular micronutrient (Cu and Zn) had positive effect on the growth and yield of rice and its quality (Liew et al., 2010). The role of zinc on cereals have already renowned and admitted. As rice is sensitive to Zn deficiency its application in the form of fertilizer significantly affects cereal's production. The deficiency of zinc may cause a drastic decline in the rice growth and yield (Alloway, 2004). Furthermore, an appropriate amount of micronutrients is decisive for the human health as well as for normal plant growth. Micronutrient Cu and Zn play an important role in the form of different mechanisms; as they regulate the enzymatic activities. Copper is required for the synthesis of lignin and act as a primal factor for N, protein and hormonal metabolism of plants. It serves as catalyst for photosynthesis, respiration, pollen formation and fertilization in rice (Dobermann and Fairhurst, 2000).

Table 1. Soil physical and chemical characteristics before planting rice

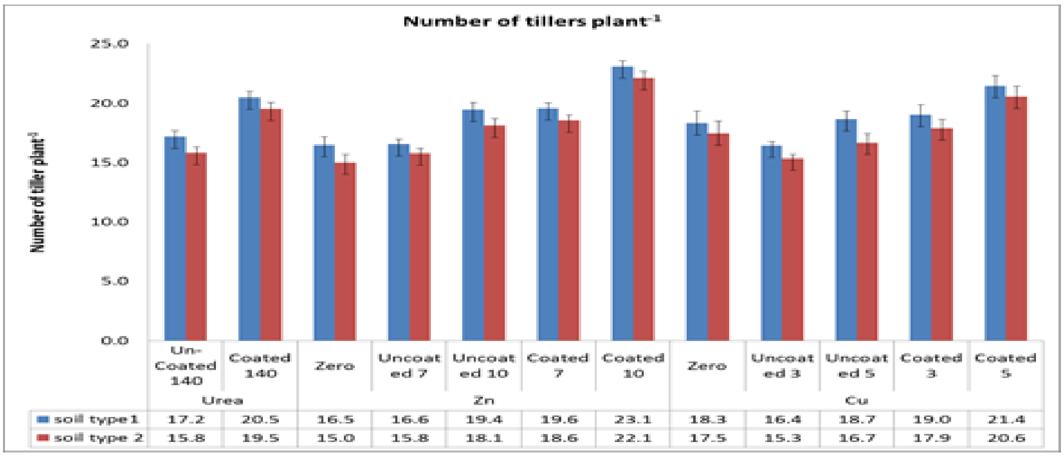
Soil Physical characteristics		
	Chempaka	Kuala Kedah
Texture	Clay loam	Silty clay
Soil Chemical Characteristics		
pH	5.12	5.29
Total N %	0.18	0.15
Extractable P mg kg^{-1}	20.5	21.9
Exchangeable K cmol (+) kg^{-1}	0.18	0.17
Zn mg kg^{-1}	0.90	1.10
Cu mg kg^{-1}	0.11	0.15

Effect of Cu and Zn Coated Urea on the Growth of Rice

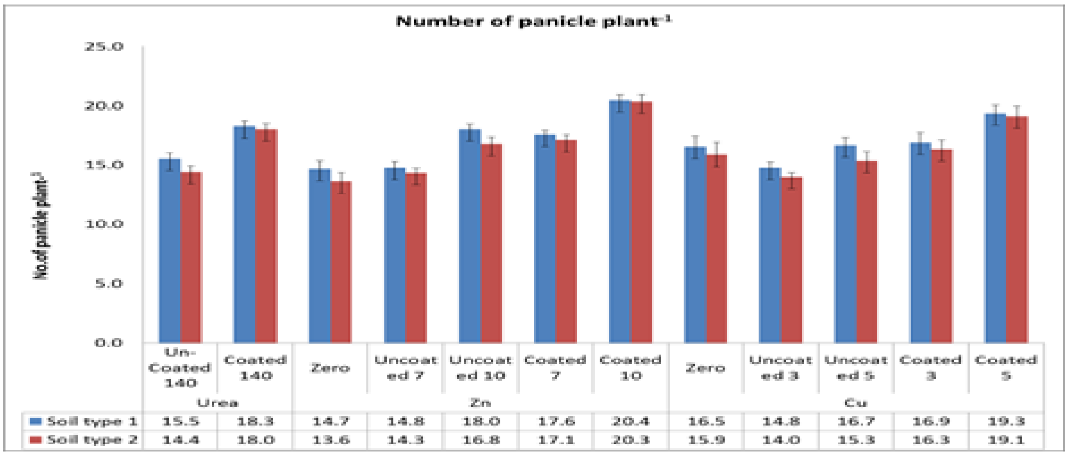
Results showed that Cu and Zn coated urea significantly affected on all the growth parameters of rice along with the chlorophyll contents and nutrients uptake. It was manifested that the rice growth parameters in terms of plant height (cm), number of tillers $plant^{-1}$, number of panicles $plant^{-1}$, panicle length $plant^{-1}$ and panicle length $panicle^{-5}$ positively responded towards Cu and Zn coated urea (Figure 1 (a to e)).



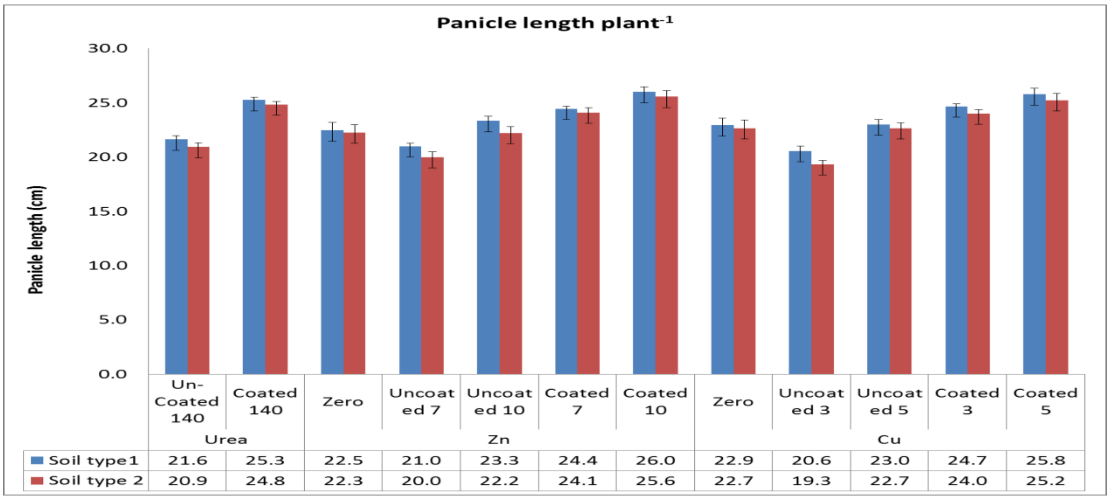
(a)



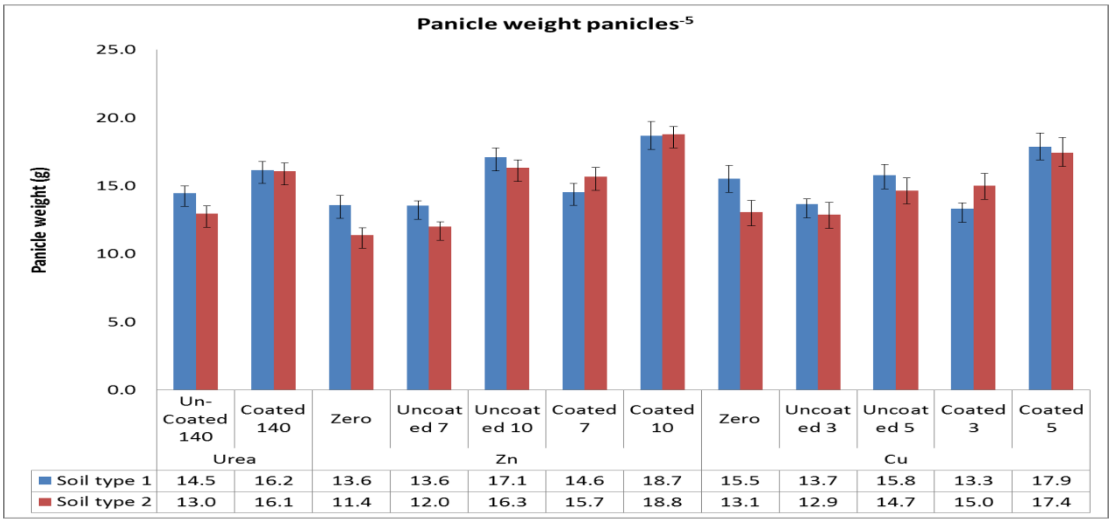
(b)



(c)



(d)



(e)

Figure 1. Effect of Cu and Zn coated urea on growth parameters of rice; (a) plant height (cm), (b) Number of tillers plant^{-1}, (c) Number of panicles plant^{-1}, (d) panicle length plant^{-1}, (e) panicle weight plant^{-1}.

Comparison between control and Cu and Zn (coated with urea and surface application) found significant difference among the various treatments. The results are in accordance with research conducted in Malaysia, where the researchers have applied combined Zn, Cu and Mo and individually. It was observed that the growth and yield of rice significantly affected with the application of combined micronutrients (Panhwar et al., 2015). The highest plant height (120cm) was observed from Cu and Zn coated urea. Significantly the higher number of tillers plant^{-1} (23), number of panicle plant^{-1} (21), panicle length plant^{-1} (26cm) and panicle weight panicle^{-5} (19g) were recorded from combined Cu and Zn coated urea. The micronutrient either applied in single attribute or in combined form can increased the growth and yield of rice. The current research has proven the progressive approach of Cu and Zn coated urea. Coating helps the fertilizer to dissolve gradually in the flooded rice soils. The synergetic influence of micronutrients can effect on the convenience of macronutrient in the soil. This action can enhance the photosynthetic activity of plant which eventually outcome with improved rice yield (Merrill and Watt, 1973). The results from the present studies are in the accordance with the research held on the role of Zn fertilizer on grain yield and some quality parameters in Iranian rice genotypes. Micronutrient application affected rice growth and interaction among micronutrients uptake, dispersal and application (Yadi, Dastan and Yasari, 2012). The special feature with the application of Zn was observed as antagonism with Fe (Imtiaz et al., 2010). The increment of Zn application in rice plant enhanced the availability of Zn and also the N-uptake (Wei, Shohag and Yang, 2012). Therefore, the highest mean values of growth and yield attributes can be possible from combined Cu and Zn application (Kumar et al., 2011) transplanting. Among the treatments, the higher values were found from the treatment that contains combination of Cu and Zn as compared to surface application of micronutrients and in an individual form. The mean values showed that the chlorophyll contents were ranged at 38.7 to 41. 3 from the coated urea which is higher than the 35.8 recorded at uncoated micronutrients treatment.

Antioxidant and photosynthetic activities of higher plants can be affected by the presence of heavy metals. Soil and Plant Analyzer Development (SPAD) used as an indicator for assessing the chlorophyll contents of plant through leaves. The SPAD values were recorded lower in the control than the treatment contains Cu and Zn coated urea (Table 2). Combined Cu and Zn coated urea helped plants to absorb more N due to their synergistic effect and N-protein synthesis therefore, the chlorophyll increased with the application of combined Cu and Zn coated urea. The similar results were obtained in wheat crop, where micronutrients were applied with the variable rates of N, the SPAD values were improved (Shi et al., 2010).

Table 2. Effect of Cu and Zn coated urea on chlorophyll contents

	Treatments	Chlorophyll contents
Uncoated Urea	NPK (control)	33.833 g
	Zn10	35.667 f
	Zn7	34.000 g
	Cu5	36.500 ef
	Cu3	35.667 f
	Zn10+Cu5	37.667 de
	Zn7+Cu5	36.167 ef
	Zn10+Cu3	36.500 ef
	Zn7+Cu3	36.500 ef
Coated Urea	Zn10	40.167 b
	Zn7	38.500 cd
	Cu5	39.50 bc
	Cu3	38.333 cd
	Zn10+Cu5	41.833 a
	Zn10+Cu3	38.833 bcd
	Zn7+Cu5	38.833 bcd
	Zn7+Cu3	39.000 bcd

Means with the same letters in column are not significantly different from each other ($p>0.05$)

Factor	F-value	P-Value	HSD Value
Treatments	46.05	0.0000	1.617

Consequences of Cu and Zn coated urea on availability of N, Cu and Zn

The micronutrient contents along with N-uptake varied with treatment effect. The significant higher values of micronutrients were found from combination of Cu and Zn coated with urea (Table 3). The application of micronutrient coated urea enhanced the N-uptake in rice plant. The concept behind the application of coated urea is slow release of urea in sub-merged conditions of rice soils. Hence the MNCU can minimize the nutrient losses and can able to provide the nutrients according to the need of the crop (Azeem et al., 2014). Zinc addition increased the Zn uptake in grain and straw, that simultaneously enhance the N-uptake (Wei et al., 2012). The results manifested that the MNCU enhance the nutrient uptake; Cu, Zn and N respectively.

Table 3 Nitrogen, Cu and Zn contents after application of Cu and Zn coated urea

Soil Chemical Characteristics	Soil1	Soil2
Total N %	0.25	0.23
Soil available Zn mg kg^{-1}	2.50	2.25
Soil available Cu mg kg^{-1}	1.51	1.65

Conclusion

The application of Cu and Zn coated urea in the combination along with the recommended doses of NPK significantly affected on the marine and riverine alluvium of Malaysian soils. All the growth parameters of rice plant, chlorophyll contents and nutrients availability increased with the application of combined Cu and Zn coated urea. Application of Cu and Zn coated urea can reduce the N-losses and enhanced its uptake. Consequently, there is a strong reasoning for the application of combined Cu and Zn coated urea, due to their synergetic effect with other nutrients in the flooded conditions of rice soils.

Recommendations

Controlled release urea can reduce N-losses by slowing its hydrolysis rate and enhance the N-contents. This experiment revealed that urea coated with Cu and Zn improved the efficiency of urea. Copper and Zn served dual role: 1) urease inhibitors and 2) essential micronutrients. Therefore, for obtaining the desired yields of rice, Cu and Zn coated urea should be applied in the rice soils across the world.

Acknowledgements

Authors are highly thankful to Higher Education Commission of Pakistan for the financial assistance to present this work at ICRES, Marmaris Turkey.

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