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Effect of soil and foliar fertilization of copper on growth and yield of rice (*Oryza sativa* L.) in *Typic haplustalfs* of Tamil Nadu

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Abstract
The impact of soil application of graded levels of copper (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 kg Cu ha^{-1}) and foliar spray (0.25% $CuSO_4$ at tillering stage, 0.25% $CuSO_4$ at tillering and flowering stage, 0.5% $CuSO_4$ at tillering stage and 0.5% $CuSO_4$ at tillering and flowering stage) on growth and yield of irrigated rice was studied by conducting field experiment in *Typic haplustalfs* where the initial soil Cu content was minimum (0.88 mg kg^{-1}). The treatment plots were replicated three times in randomized block design. The results revealed that the Cu application increased the growth and yield of rice crop significantly.
Soil application of Cu at 1.5 kg ha^{-1} recorded the highest plant height (115.4cm), number of productive tillers hill^{-1}(37.7), number of panicles hill^{-1}(26.3), number of grains panicle^{-1}(441), number of filled grains panicle $^{-1}$(428.7), grain yield (4709kgha^{-1}), straw yield (8364kgha^{-1}) and reduced number of ill filled grains panicle^{-1} (12.3). Among the graded levels of Cu application *et al* ranging from 0 to 3.0 kg Cu ha^{-1} as copper sulphate, it was observed that the yield of rice increased progressively with increasing levels of Cu, attaining the highest yield at 1.5kg Cu ha^{-1} level and further increasing the Cu level declined the yield.

Keywords: Foliar fertilization, copper, growth, yield, rice (*Oryza sativa* L.), *Typic haplustalfs*

Introduction
Copper is one of the most important micronutrients, essential for plant growth (Alloway, 1995; [4] Doberman and Fairhurst, 2000) [7]. It is an integral component of numerous enzymes, and is actively involved in lignification (Doberman and Fairhurst, 2000) [7] .It is an essential micronutrient for plants but can be toxic at higher concentrations. High levels of Cu were found to inhibit the normal growth and development of plants. Cu deficiency in soil affects the metabolic processes of rice plants specifically photosynthesis and respiration. It can lead to reduced pollen viability and increases sterility in rice grain resulting in a decrease in the yield of rice (Ambak and Tadano, 1991) [5].

Rice (*Oryza sativa*) is one of the major staple foods, and feeds more than half of the world population. Among the Indian states, Tamil Nadu is the one of the leading rice growing states which contributes 8 per cent of national rice production with 5.34 million tons from an area of 1.97 million hectares, with an average productivity of 3.19 t ha^{-1} (Indiastat, 2017). Indian soils are extensively deficient in micronutrients and 5.4 per cent soils of India recorded Cu deficiency. The total copper content in Indian soils ranged from 1.8 to 960 mg kg^{-1} and the available Cu content ranged from 0.10 to 378 mg kg^{-1}. More than 25 per cent of Cu deficiency was recorded in the soils of Tamil Nadu (Shukla *et al*., 2014) [12] In wetland rice soils, the availability of water soluble Cu decreases due to decrease in redox potential (Ponnamperuma, 1981) [11].

To alleviate Cu deficiency, it is normally applied in the form of $CuSO_4.5H_2O$. There is no recommendation of Cu fertilization in the rice soils of Tamil Nadu. Hence, fixing the optimum dose of copper to rectify the deficiency in the rice soils of this region is highly important to enhance the productivity of rice.

Materials and Methods
A field experiment was conducted in *Typic haplustalfs* to study the response of rice crop to the graded levels of copper. The experiment was laid out in randomized block design (RBD) with eleven treatments replicated thrice. Plot size of 4m×4m (16 m^2) was adopted with buffer

channel around each plot in the experimental field. The field experiment was conducted with paddy, variety TKM 13 (medium duration) as a test crop.

Treatment details

T_1 - RDF alone
T_2 - RDF + 0.5 kg Cu ha^{-1}
T_3 - RDF + 1.0 kg Cu ha^{-1}
T_4 - RDF + 1.5 kg Cu ha^{-1}
T_5 - RDF + 2.0 kg Cu ha^{-1}
T_6 - RDF + 2.5 kg Cu ha^{-1}
T_7 - RDF + 3.0 kg Cu ha^{-1}
T_8 - RDF + Foliar spray of 0.25 per cent $CuSO_4$ at tillering stage
T_9 - RDF + Foliar spray of 0.25 per cent $CuSO_4$ at tillering stage and flowering stage
T_{10} - RDF +Foliar spray of 0.5 per cent $CuSO_4$ at tillering stage
T_{11} - RDF +Foliar spray of 0.5 per cent $CuSO_4$ at tillering stage and flowering stage.

As per the treatment schedule, nitrogen (N), phosphorous (P) and potassium (K) were applied at the rate of 150:50:50 kg ha^{-1} respectively. Entire dose of P was applied basally and N and K were applied in three equal splits as basal, active tillering stage and panicle initiation stage. The graded levels of copper (0.5,1.0,1.5, 2.0,2.5,3.0 kg ha^{-1}) were mixed with 25 kg of sand for uniform distribution and the mixture was broadcast basally at the time of transplanting as per treatment schedule (T_2 to T_7).The Cu fertilizer was applied in the form of $CuSO_4.5H_2O$. Copper sulphate at 0.25 and 0.5 per cent was applied in the form of foliar spray at the time of and flowering as per the treatment schedule (T_8 to T_{11}).

In the experimental fields, the bio metric observations (plant height and number of productive tillers hill^{-1}), yield attributes (number of panicles hill^{-1}, number of grains panicle^{-1}, number of filled grains panicle^{-1} and number ill filled grains panicle^{-1}) and yield of grain and straw were recorded at harvest stage.

Statistical analysis was performed using analysis of variance (ANOVA) for Randomized Block Design (Gomez and Gomez, 1984). The treatment means were compared at the $p<0.05$ level using LSD for all the parameters.

Results and Discussion

Initial soil analysis (Table 1)

The soil analysis before start of field experiment revealed that it belonged to sandy clay loam, indicating moderately fine textured category. The value of physical properties *viz.*, bulk density, particle density, porosity and water holding capacity were 1.41 (Mg m^{-3}), 2.5 (Mg m^{-3}), 55.6(%) and 35.3(%) respectively. The soil reaction was slightly alkaline (8.1) in nature and soluble salt content indicated non-saline status 0.21 (ds m^{-1}). The soil organic carbon content was 4.1 g kg^{-1} which indicated medium status. The cation exchange capacity and $CaCO_3$ contents of the soil were 24.8 CMOL (p+) kg^{-1} and 6.25 per cent respectively. The available nutrients status of soil in respect of NPK revealed that N was in low status (201.6kg ha^{-1}) whereas P and K were in medium (20.0kg ha^{-1}) and high status (320kgha^{-1}) respectively. The DTPA extractable Fe, MN and Zn were sufficient in the experimental soil recording a value of 18.2, 5.25 and 3.02 mg kg^{-1}.The available Cu (DTPA extractable Cu) was 0.88mg kg^{-1}which indicated the low status.

Table 1:.Physico-chemical properties of initial soil

1. Physical properties	Values
Bulk density(Mg m^3)	1.41
Partial density(Mg m^3)	2.5
Porosity (%)	55.6
2. Mechanical analysis	
Coarse sand (%)	22.5
Fine sand (%)	38.2
Silt (%)	9.1
Clay (%)	30.1
Textural class	Sandy clay loam
3. Electro chemical properties	
pH	8.1
EC (ds m^{-1})	0.21
CEC (c MOL (p+) kg^{-1})	24.8
4. Chemical properties	
Organic carbon (g kg^{-1})	4.1
Available Nitrogen(kg ha^{-1})	201.6
Available Phosphorus (kg ha^{-1})	20.0
Available Potassium (kg ha^{-1})	320
Available Sulphur (mg kg^{-1})	8.5
DTPA extractable Fe (mg kg^{-1})	18.2
DTPA extractable Zn (mg kg^{-1})	3.02
DTPA extractable MN (mg kg^{-1})	5.25
DTPA extractable Cu (mg kg^{-1})	0.88
Exchangeable Ca^{2+}(CMOL (p+)kg^{-1})	13.0
Exchangeable mg$^{2+($CMOL (p+)kg^{-1})	7.2
Exchangeable Na^+ (CMOL (p+)kg^{-1})	2.4
Exchangeable K^+ (CMOL (p+)kg^{-1})	1.2
$CaCO_3$ (%)	6.25

Growth attributes

Plant height and Number of productive tillers (Table 2)

Table 2: Effect of graded levels of copper on plant height (cm) and number of productive Tillers hill^{-1}at different growth stages of rice. (Mean values of three replications)

Treatments	Plant height (cm)			Number of productive tillers hill^{-1}		
	Active tillering stage	Panicle initiation stage	Harvesting stage	Active tillering stage	Panicle initiation stage	Harvesting stage
T_1	43.5	54.9	57.7	9.3	12.0	15.3
T_2	62.8	78.3	85.2	16.6	22.6	28.4
T_3	64.2	80.5	88.5	17.0	25.1	29.6
T_4	76.0	100.6	115.4	24.6	33.7	37.7
T_5	78.4	97.8	110.3	23.5	30.4	35.0
T_6	71.5	87.2	96.7	19.8	27.9	32.4
T_7	55.9	68.4	75.5	14.4	18.0	24.2
T_8	60.5	74.9	83.7	15.8	21.2	26.6
T_9	74.8	94.6	99.9	20.3	28.4	33.8
T_{10}	51.3	63.5	68.4	12.9	16.2	20.3
T_{11}	47.6	60.0	63.5	11.8	13.9	17.2
Mean	61.33	76.8	84.0	16.27	21.59	26.30
SED	1.55	2.55	3.02	0.56	1.01	1.15
CD ($P=0.05$)	3.89	5.86	6.13	1.40	2.23	2.52

Soil and foliar application of Cu significantly increased the plant height from tillering to harvest stage. In the present study, the plant height ranged from 43.50 to 78.4, 54.9 to 100.6 and 57.7 to 115.4cm at tillering, panicle initiation and harvest stages respectively. Among the graded levels of Cu, soil application of 1.5 kg Cu ha^{-1} (T_4) recorded the highest plant height but it was on par with 2.0kg Cu ha^{-1} (T_5) and foliar spray of 0.25 per cent $CuSO_4$ (T_9). The Cu treated plots and the control plots showed significant difference in the plant height of rice crop and the increasing dose of Cu application beyond 2.0 kg Cu ha^{-1} retarded the growth of rice crop. Thus the plants in a soil with deficit copper level was found to record the lowest plant height and reduced tillering which could be attributed to the loss of apical dominance of main stem. Similar results of low Cu on plant growth inhibition have also been recorded by various authors (Agarwala and Sharma, 1976; Agarwala and Sharma, 1979; Kumar *et al*., 2009; Silviya *et al*., 2017) [1, 2, 9, 13].

Dobermann and Fairhust (2000) [7] reported that the active role of Cu in nitrogen, protein metabolism, hormone metabolism, photosynthesis, respiration and they were also involved in auxin production which increased the vegetative growth of rice crop. In the present investigation rice growth got decreased in treatments T_{10} and T_{11} where foliar spray of Cu was applied at 0.5 per cent indicating its toxic concentration on plant growth. Similar result was recorded by Xu *et al*. (2005) [15] who reported that the biomass response to Cu were associated with its inhibition on photosynthesis, because excessive Cu result in chlorophyll decomposition or degradation.

Yield and yield attributes (Table 3 and 4)

Application of Cu significantly increased the number of panicles hill^{-1} and the highest value was recorded in plants received copper at 1.5 kg ha^{-1}(T_4) followed by Cu at 2 kg ha^{-1}(T_5) level (Table 3). This may be due to activation of more enzymes by Cu ions in plants by building and converting amino-acids to proteins which contributed for panicle increase. Similar results were recorded by Dobermann and Fairhust (2000) [7], Xu *et al.* (2005) [15], Alam *et al.* (2010) [3], Liew *et al.* (2012) [10] and Das (2014) [6].

Number of grains panicle^{-1}, number of filled grains panicle^{-1} were significantly increased in plants applied with 1.5 kg Cu ha^{-1} (T_4) followed by 2.0 kg Cu ha^{-1}(T_5) (Table 3). Number of ill filled grains was significantly reduced in plants received Cu at 1.5kgha^{-1} (T_4). The next best treatment in reducing number of ill filled grains was 2.0kg Cu ha^{-1}(T_5). In the present study, the adequate supply of Cu fertilizers to the plants inclined the plant Cu uptake by improving the enzymatic activities and carbohydrate assimilation in rice panicles. The presence of Cu increased the pollen viability and fertility thus it enhanced the grain filling whereas in the control plots the chaffy grains got increased due to the poor supply of Cu which decreased the grain filling. Similar findings were observed by Doberman and Fairhust (2000) [7], Alam *et al.* (2010) [3], Liew *et al.* (2012) [10] and Das (2014) [6].

The effect of graded levels of copper showed a positive response to the grain yield of rice. The soil application of Cu at 1.5kg Cu ha^{-1} (T_4) registered maximum grain yield of 5709 kg ha^{-1} followed by the application of Cu at 2kg Cu ha^{-1}(T_5) with the grain yield of 5373kg ha^{-1} which was on par with the treatment received foliar spray of 0.25 per cent $CuSO_4$ at tillering stage and flowering stage (5077kgha^{-1}). The T_1 treatment (RDF alone) has recorded lowest grain yield of 4041kgha^{-1} among all the treatments.

Among the graded levels of Cu application ranging from 0 to 3.0kg Cu ha^{-1} as copper sulphate, it was observed that the yield of rice increased progressively with increasing levels of Cu, attaining the highest yield at 1.5 kg Cu ha^{-1} level and further increasing the Cu level declined the yield. This could be due to adequate Cu supply might have been improved the photosynthetic activity which enable rice plant to accumulate sufficient photosynthates and its translocation resulted in more number of filled grains with increased test weight and ultimately led to higher grain yield. Further, Cu application resulted in an increase in the number of productive tillers, panicle length, and number of filled grains per panicle and decreased the percentage of chaffy grains. These findings are supported by Doberman and Fairhust (2000) [7], Alam *et al.* (2010) [3], Liew *et al.* (2012) [10] Das (2014) [6] and Silviya *et al*. (2017) [13].

Straw yield of rice was significantly influenced by the copper application (Table 4). The maximum yield was recorded in the treatment T_4 where Cu was applied at 1.5kg ha^{-1} followed by 2.0kg Cu ha^{-1}(T_5).This was mainly due to optimum Cu application resulted in an increase in the number of tillers per hill which would have amounted for higher straw yield. The results were in agreement with the findings of Kumar *et al*. (2009) [9] and Silviya *et al*. (2017) [13].

Further, it was observed that foliar spray of copper above 0.25 per cent caused a significant decrease in grain and straw yield, which may be attributed to injurious effect of high concentration of Cu in grain and straw. Due to the inhibition of photosynthesis caused by excess Cu availability holds back the rate of chlorophyll synthesis and decreased the yield of rice (Table 4) with higher dose of Cu application (T_8, T_{10} and T_{11}).

Table 3: Effect of graded levels of copper on yield attributes of rice (Mean values of three replications)

Treatments	Number of panicles hill^{-1}	Number of grains panicle^{-1}	Number of filled grains panicle^{-1}	Number of ill filled grains panicle^{-1}	Panicle length (cm)	Panicle weight (g)
T_1	12.3	252.7	201.6	51.1	20.3	2.1
T_2	19.1	336.3	300.5	35.8	21.9	3.6
T_3	19.5	342.8	304.9	37.9	22.2	3.8
T_4	26.3	441.0	428.7	12.3	23.9	5.6
T_5	24.5	408.0	394.0	14.0	23.5	5.0
T_6	21,4	368.5	341.6	26.9	22.7	4.3
T_7	17.0	304.6	266.5	38.1	21.4	3.1
T_8	18.7	328.7	297.3	31.4	21.8	3.5
T_9	22.2	376.0	360.0	16.0	23.0	4.5
T_{10}	15.0	300.7	258.7	37.9	21.0	2.8
T_{11}	14.0	285.3	247.4	42.0	20.8	2.5
Mean	18.37	336.38	302.57	28.42	22.02	3.57
SED	0.79	13.67	13.15	1.44	1.209	0.15
CD (*P=0.05*)	1.48	28.51	28.60	2.99	NS	0.33

Table 4: Effect of graded levels of copper on grain and straw yield of rice (Mean values of three replications)

Treatments	Yield (kg ha^{-1})		
	Grain yield	Per cent increase over control	Straw yield
T_1	4041	-	5583
T_2	4804	19.0	6579
T_3	4881	20.8	6797
T_4	5709	41.3	8364
T_5	5373	32.9	7851
T_6	4982	23.3	7235
T_7	4661	15.3	6398
T_8	4779	18.3	6586
T_9	5077	25.6	7395
T_{10}	4605	13.9	6238
T_{11}	4568	13.0	6021
Mean	4843.91		6778.46
SEd	143	-	228
CD (P=0.05)	308	-	479

Conclusion

The results of the present study indicated that the Cu application improved the growth and yield attributes and yield of rice crop. Application of Cu at 1.5kg ha^{-1} favorably influenced the number of productive tillers per hill, panicle length, and number of filled grains per panicle, percentage of chaffy grains, grain and straw yield of rice. The grain and straw yields were enhanced by 40.3 per cent and 49.8 per cent respectively over control by application of 1.5kg Cu ha$^{-1.}$ Therefore it may be concluded that for obtaining higher rice yield in Cu deficient soils of *Typic haplustalfs* of Tamil Nadu, 1.5kg Cu ha^{-1} may be recommended.

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