

Original Research Article

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Rice Crop Response to Applied Copper under Varying Soil Available Copper Status at Tamilnadu, India

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ABSTRACT

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The impact of graded levels of Cu (0, 0.5, 1.00, 1.50, 2.00, 2.50 kg ha⁻¹) on the growth and yield of irrigated rice was studied by conducting field experiments in major rice growing tracts having varied soil Cu status at Tamil Nadu. The treatment plots were replicated four times in Randomized Block Design. Application of Cu @ 1.5 kg ha⁻¹ recorded the highest plant height (95.0 cm), number of productive tillers m⁻² (323.6), number of filled grains panicle⁻¹ (107.6), test grain weight (24.5 g), grain yield (6.50 t ha⁻¹) and straw yield (7.74 t ha⁻¹). The highest values were recorded in the location No.4 where the initial soil Cu content was minimum (0.84 mg kg⁻¹). The results indicated that, the Cu fertilization significantly increased the growth and yield parameters of rice crop in Cu deficient soils while the soils with adequate or high Cu status showed declining response.

Introduction

The world's population is expected to hike about 9.7 billion by 2050 and the Indian population may increase to 1.6 billion from the current level of 1.2 billion (Shukla *et al.*, 2014). Among the existing population, it has been reported that about 2 billion people of the world's population have been affected by micronutrient malnutrition. As anticipated, deficiencies of micronutrients are highly prevalent in places where cereals with low nutritional quality are the main diet (Cakmak, 2008). In order to feed the increasing population and to overcome the nutritional disorder, agricultural intensification is required which will improve the food production and it will meet out the dietary

nutrient requirement of humans. More than half of the world's population consumes rice than other cereals (FAO, 2013). About 92 per cent of the world's rice are produced and consumed in Asia and among the Asian continent; India has the largest area of 29.4 per cent global area under rice cultivation (Humaira *et al.*, 2015). In Indian states, Tamil Nadu stays third in the rice production (Mahata *et al.*, 2012).

Micronutrients play a vital role in crop growth, crop productivity, soil fertility and human nutrition (Patel *et al.*, 2015). Arnon and Stout (1939) proposed that, Cu is an essential element for plant growth. Among the

micronutrients, Cu plays an important role in the crop growth by increasing the tillering and pollen viability of the crop (Das, 2014). Copper is a component of large number of proteins and enzymes like plastocyanin, diamine oxidase and ascorbate oxidases and Cu containing enzymes play an important role in photosynthesis, respiration and in lignin formation. It acts as a structural element in regulatory proteins and involves in photosynthesis electron transport, mitochondrial respiration, stress responses, cell wall metabolism and hormone signaling. The cereal crops show white tips as Cu deficiency symptoms and the deficiency of such micronutrient has been identified as the main limiting factor for crop yield, food quality and human health (Alloway, 2008).

Indian soils are extensively deficient in micronutrients and 5.4 per cent soils of India recorded Cu deficiency. The total Cu 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 high in the soils of Tamil Nadu (Shukla *et al.*, 2014). It reveals that, each essential nutrient has its own and specific role in the plant growth. Their presence in the required quantity is a must for completing the plant's life cycle. So, the rice crop also needs adequate amount of Cu for obtaining high yield which cannot be achieved by applying the NPK fertilizers alone. The soil survey, soil analysis and multi location trials will pave the way in enhancing the micronutrient content in the food crops by adopting location specific micronutrient recommendations. Keeping this in view, the present study was carried out.

Materials and Methods

The research work involved soil survey, soil sample collection, soil analysis and multi location field experimentations.

Soil survey and analysis

The soil survey was conducted in the major rice growing tracts of Tamil Nadu as Erode, Coimbatore, Tirunelveli and Tiruvarur districts. A sum of 144 surface soil samples was collected from the identified areas; they were processed and analyzed for various physico-chemical parameters. By following the International Pipette method (Piper, 1966) the textural classes of the soils were determined. The 1:2.5 soil-water suspensions were used to determine the pH of the soil by using pH meter and the EC through conductivity meter.

The Neutral Normal NH₄OAc was used to determine the cation exchange capacity of the soil (Schollnberger and Dreibeis, 1930). The available N, P and K was determined through alkaline permanganate method (Subbiah and Asija, 1956), 0.5 M NaHCO₃ (Olsen *et al.*, 1954) and Neutral Normal NH₄OAc method (Standford and English, 1949), respectively. The available Cu status in the soil was determined through DTPA extractable method proposed by Lindsay and Norvell (1978).

Field experimentation

The soils of four different districts (Erode, Coimbatore, Tirunelveli and Tiruvarur districts) of Tamil Nadu were categorized into six categories based on the soil available Cu status as ≤ 0.6 , 0.6 – 0.9, 0.9 – 1.2, 1.2 – 1.5, 1.5 – 1.8 and ≥ 1.8 mg kg⁻¹ of Cu. The field experiments (two experiments per each category) were conducted in twelve locations to study the response of rice crop to the application of graded levels of Cu fertilizers (0, 0.5, 1.0, 1.5, 2.0 and 2.5 kg ha⁻¹Cu). The experimental plots were designed by following Randomized Block Design with four replications. The rice variety ASD 16 was used as the test crop.

In all the treatment plots, the NPK application was carried out uniformly by following the general recommendation as 150:50:50 kg ha⁻¹ of N, P₂O₅ and K₂O. Nitrogen was applied in four equal splits as basal dose, active tillering, panicle initiation and heading stages. Entire dose of Phosphorous was applied as a basal dose. Potassium was applied in two equal splits as basal dose and at panicle initiation stage. The Cu fertilizer was applied in the form of CuSO₄. Need based intercultural operations were carried out during the cropping period. In the experimental fields, the biometric observations (plant height and number of productive tillers per sq.m.), yield parameters (number of filled grains per panicle and test grain weight) and yield of grain and straw were recorded at harvest stage.

Results and Discussion

The results of the soil analysis, biometric observations and yield parameters of the experimental fields were recorded as follows:

Soil analysis

The soils of the experimental fields differed in their soil properties. The textural class of the study locations varied as sandy loam, sandy clay loam, clay loam and clay. The soils recorded neutral pH in a range of 6.50 to 7.85. The EC of the experimental soils were free from soil salinity. The available N, P and K of the soil fall under low – medium, medium and medium categories, respectively. The available Cu content in the soils ranged from 0.33 to 2.12 mg kg⁻¹ of Cu (Table 1).

Rice growth parameters

Application of graded levels of Cu increased the height of the plants. In the fourth location (L4), the highest plant height of 94.1 cm was recorded (Table 2). The lowest plant height of

89.3 cm was recorded in the first location (L1). Among the graded levels of Cu application, the T4 (1.50 kg ha⁻¹ of Cu) recorded the highest plant height of 95.0 cm, the increase being 7.2 per cent over control (T1). Similarly, the application of Cu @ 1.50 kg ha⁻¹ recorded the highest productive tillers of 323.6 m⁻², which showed a 24.6 per cent increase over control and the control (- Cu) plots recorded the lowest productive tiller counts of 243.9 m⁻² (Table 2). The fourth location recorded the highest number (315.4 tillers m⁻²) and the first location recorded the minimum number of tillers (248.9 tillers m⁻²).

The soils with low initial Cu status showed significant response to the Cu application which is in agreement with the findings of Liew *et al.*, (2012) and Das (2014). Dobermann and Fairhurst (2000) indicated that the active role of Cu in nitrogen, protein metabolism, hormone metabolism, photosynthesis, respiration and they were also involved in the auxin production which increased the vegetative growth of rice crop.

The rice growth got decreased by the application of Cu in the soils with high Cu content and the same result was recorded by Xu *et al.*, (2005) which stated that the biomass responses to Cu were associated with its inhibition on photosynthesis, because excessive Cu could restrain chlorophyll synthesis or result in chlorophyll decomposition.

Rice yield components

The yield components such as number of filled grains per panicle and test (1000 grains) grain weight showed alike response to the Cu application (Table 3). An increase of 12.7 and 4.5 per cent of filled grains and test grain weight respectively over control was recorded by the application of 1.50 kg ha⁻¹ of Cu (T4).

Table.1 Initial soil properties of various field experiments

Locations	Soil texture	pH	EC (dSm⁻¹)	CEC (Cmol(p+)kg⁻¹)	Available N (kg ha⁻¹)	Available P (kg ha⁻¹)	Available K (kg ha⁻¹)	Available Cu (mg kg⁻¹)
L1	Sandy Loam	6.54	0.14	13.2	389	18	197	0.33
L2	Sandy Clay Loam	6.55	0.15	17.3	185	20	128	0.53
L3	Sandy Loam	7.85	0.25	13.5	145	15	175	0.63
L4	Sandy Clay Loam	6.70	0.17	16.8	145	13	225	0.84
L5	Sandy Clay Loam	7.38	0.15	16.5	398	21	220	1.01
L6	Clay	7.52	0.12	21.8	158	15	270	1.11
L7	Clay Loam	7.40	0.18	15.8	130	17	272	1.28
L8	Sandy Clay Loam	7.50	0.23	17.2	182	12	235	1.33
L9	Clay Loam	7.55	0.25	15.2	192	13	165	1.57
L10	Sandy Loam	7.50	0.25	13.2	185	19	185	1.61
L11	Sandy Clay Loam	7.05	0.12	17.4	179	15	120	1.91
L12	Sandy Loam	6.50	0.17	13.5	198	14	142	2.12

Table.2 Effect of Cu on plant height (cm) and number of productive tillers m⁻² of rice crop at harvest stage

Cu levels (kg ha ⁻¹)	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Pooled mean	Per cent over control
Plant height (cm)														
0.00	83.4	85.4	85.7	87.2	87.6	89.0	89.4	89.8	90.0	90.2	90.5	90.7	88.2	-
0.50	86.2	88.0	88.3	90.7	90.4	89.7	89.9	90.2	90.5	90.8	93.1	93.0	90.1	2.1
1.00	88.2	90.3	91.1	92.2	92.0	91.0	96.4	96.0	94.2	93.8	92.0	92.0	92.4	4.5
1.50	94.5	96.4	97.5	99.8	99.2	98.2	93.5	93.4	92.5	92.2	91.8	91.6	95.0	7.2
2.00	92.5	95.0	96.0	98.5	98.3	96.5	92.9	93.0	91.8	91.8	91.3	90.9	94.0	6.2
2.50	90.7	91.2	95.4	96.3	96.0	95.0	92.5	92.2	91.2	91.5	90.7	90.9	92.8	4.9
Mean	89.3	91.1	92.3	94.1	93.9	93.2	92.4	92.4	91.7	91.7	91.6	91.5		
SEd	0.63	0.8	0.52	0.91	0.89	0.78	0.52	1.05	0.89	0.76	0.69	0.45		
CD (5%)	1.34	1.71	1.12	1.93	1.89	1.66	1.11	2.24	1.9	1.63	1.48	0.96		
Number of productive tillers m⁻²														
0.00	176	192	214	234	230	252	251	256	273	278	284	288	243.9	-
0.50	192	208	240	272	288	272	288	288	288	288	304	304	269.3	9.4
1.00	251	272	293	304	320	272	324	320	320	304	288	288	296.4	17.7
1.50	341	352	368	416	336	336	304	304	283	288	283	272	323.6	24.6
2.00	277	288	320	363	320	320	288	288	288	272	288	272	298.7	18.3
2.50	256	251	272	304	304	304	288	272	277	277	256	256	276.4	11.8
Mean	248.9	260.5	284.5	315.4	299.7	292.7	290.5	288.0	288.1	284.5	283.8	280.0		
SEd	3.08	2.68	2.38	3.44	2.69	2.25	14.8	2.41	2.34	2.46	2.53	2.41		
CD (5%)	6.57	5.71	5.08	7.32	5.69	4.79	31.5	5.14	4.99	5.24	5.38	5.13		

Table.3 Effect of Cu on number of filled grains per panicle and test grain weight (g) of rice crop at harvest stage

Cu levels (kg ha ⁻¹)	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Pooled mean	Per cent over control
Number of filled grains per panicle														
0.00	85	88	89	91	93	94	95	97	98	98	99	100	93.9	-
0.50	94	96	97	100	99	97	97	96	93	91	106	104	97.5	3.7
1.00	95	99	100	105	104	102	113	112	110	110	101	101	104.3	9.9
1.50	102	106	108	116	114	113	109	109	108	105	101	101	107.6	12.7
2.00	98	102	103	109	107	106	103	103	103	102	101	101	103.2	9.0
2.50	97	100	102	107	105	105	100	100	102	102	100	100	101.7	7.7
Mean	95.2	98.5	99.8	104.7	103.7	102.9	102.8	102.8	102.3	101.3	101.3	101.2		
SEd	0.87	0.86	0.94	0.73	0.87	0.96	0.71	0.61	1.02	0.74	0.87	1.11		
CD (5%)	1.85	1.82	1.99	1.56	1.85	2.05	1.52	1.29	2.17	1.57	1.85	2.36		
Test grain weight (g)														
0.00	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.6	23.6	23.6	23.7	23.7	23.4	-
0.50	23.2	23.5	23.5	23.8	23.7	23.6	23.6	23.6	23.7	23.6	24.0	24.0	23.6	0.9
1.00	23.8	24.0	24.2	24.6	24.4	24.0	24.6	24.5	24.3	24.1	23.7	23.6	24.1	2.9
1.50	24.4	25.0	25.0	25.8	25.4	24.7	24.5	24.4	23.8	23.7	23.7	23.5	24.5	4.5
2.00	24.1	24.1	24.4	25.0	24.7	24.2	23.7	23.6	23.7	23.6	23.6	23.5	24.0	2.5
2.50	24.0	24.1	24.2	24.7	24.7	24.2	23.4	23.3	23.8	23.4	23.6	23.2	23.9	2.1
Mean	23.7	23.9	24.1	24.5	24.4	24.0	23.9	23.8	23.8	23.7	23.7	23.6		
SEd	0.19	0.13	0.25	0.14	0.15	0.29	0.25	0.17	0.16	0.15	0.12	0.1		
CD (5%)	0.41	0.28	0.53	0.29	0.32	0.61	0.52	0.37	0.34	0.31	0.25	0.22		

Table.4 Effect of Cu on the grain and straw yield (t ha⁻¹) of rice crop

Cu levels (kg ha ⁻¹)	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Pooled mean	Per cent over control
Grain yield (t ha⁻¹)														
0.00	3.85	4.05	4.16	4.38	4.45	4.58	4.63	4.70	4.77	4.84	4.98	5.07	4.54	-
0.50	4.77	5.12	5.28	5.61	5.58	5.72	5.92	5.88	5.85	5.80	6.21	6.07	5.65	19.6
1.00	5.97	6.21	6.38	6.25	6.00	6.38	6.68	6.60	6.44	6.38	5.60	5.45	6.20	26.8
1.50	6.83	6.83	7.05	7.28	7.14	6.87	6.47	6.40	6.17	6.07	5.50	5.42	6.50	30.2
2.00	6.55	6.70	6.80	6.98	6.93	6.66	6.40	6.25	5.92	5.85	5.32	5.28	6.30	27.9
2.50	6.53	6.69	6.75	6.90	6.90	6.54	5.75	5.70	5.40	5.22	5.12	5.10	6.05	24.9
Mean	5.75	5.93	6.07	6.23	6.17	6.13	5.98	5.92	5.76	5.69	5.46	5.40		
SEd	0.04	0.07	0.05	0.07	0.05	0.07	0.06	0.25	0.04	0.05	0.04	0.04		
CD (5%)	0.08	0.16	0.11	0.15	0.10	0.14	0.13	0.53	0.09	0.12	0.09	0.09		
Straw yield (t ha⁻¹)														
0.00	5.04	5.25	5.38	5.58	5.63	5.80	5.87	5.94	5.98	6.03	6.25	6.30	5.75	-
0.50	6.04	6.35	6.52	6.84	6.80	6.97	7.14	7.12	7.08	7.04	7.42	7.33	6.89	16.5
1.00	7.26	7.43	7.60	7.47	7.33	7.60	7.92	7.85	7.68	7.62	6.85	6.68	7.44	22.7
1.50	8.07	8.22	8.29	8.48	8.34	8.11	7.72	7.62	7.40	7.30	6.72	6.63	7.74	25.7
2.00	7.79	7.94	8.02	8.30	8.22	7.92	7.65	7.42	7.14	7.07	6.55	6.52	7.54	23.7
2.50	7.72	7.90	7.95	8.14	8.12	7.78	6.98	6.95	6.65	6.45	6.32	6.32	7.27	20.9
Mean	6.99	7.18	7.29	7.47	7.41	7.36	7.21	7.15	6.99	6.92	6.68	6.63		
SEd	0.05	0.05	0.08	0.06	0.16	0.05	0.06	0.06	0.08	0.05	0.04	0.06		
CD (5%)	0.10	0.11	0.18	0.12	0.33	0.09	0.14	0.12	0.16	0.12	0.09	0.13		

In the fourth location, the highest number of filled grains per panicle (104.7) and test grain weight (24.5 g) was recorded. The number of filled grains per panicle was found low in the first location (L1) and the lowest test grain was recorded in the twelfth location (L12).

The yield of grain and straw was significantly increased with the application of graded Cu doses (Table 4). The fourth location which was with minimum initial soil Cu content recorded the highest yield of grain and straw (6.23 and 7.47 t ha⁻¹), respectively. The lowest yield of grain and straw was recorded in L12, where the initial soil Cu status was high. Among different treatments, the treatment with 1.50 kg ha⁻¹ of Cu (T4) registered the highest yield of 6.50 and 7.74 t ha⁻¹ of grains and straw respectively, and the yield increase being 30.2 and 25.7 per cent respectively over control was noted. The lowest mean yield was recorded in the control treatment with 4.54 t ha⁻¹ of grains and 5.75 t ha⁻¹ of straw.

The positive effect of Cu on grain yield of rice observed in the present study might be attributed to enhancement of the pollen viability, grain formation and grain filling by improving the enzyme activities and the absorbed Cu increased the content of photosynthetic pigments in the plants resulting in the improvement of yield parameters of rice (Khush and Peng, 1996). They also stated that the translocation of carbohydrates produced in the leaves and stems into the grains were a pre-requisite for higher grain filling rate thus Cu helps in increasing the grain filling in rice crop. Similar findings were recorded by Dobermann and Fairhurst (2000), Liew *et al.*, (2012) and Das (2014). Due to the inhibition of photosynthesis caused by the excess Cu availability holds back the rate of chlorophyll synthesis and that decreased the yield of rice in the soils with higher soil Cu status (Xu *et al.*, 2005).

In conclusion, the findings of this study have shown that the application of Cu enhanced the grain and straw yields by 30.2 and 25.7 per cent increase over control. The yield increment was due to higher percentage increase of filled grains per panicle and test grain weight. The increase was noted due to the enhancement of photosynthesis metabolism which was promoted by the absorbed Cu ions by the crop. The study defines that, the soils with low initial Cu status responded positively to the application of Cu and the soils with high Cu status showed very less response to the Cu application. Therefore, it is concluded that, for obtaining higher yield in the Cu deficient soils 1.5 kg ha⁻¹ of Cu (6 kg CuSO₄ ha⁻¹) may be recommended.

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